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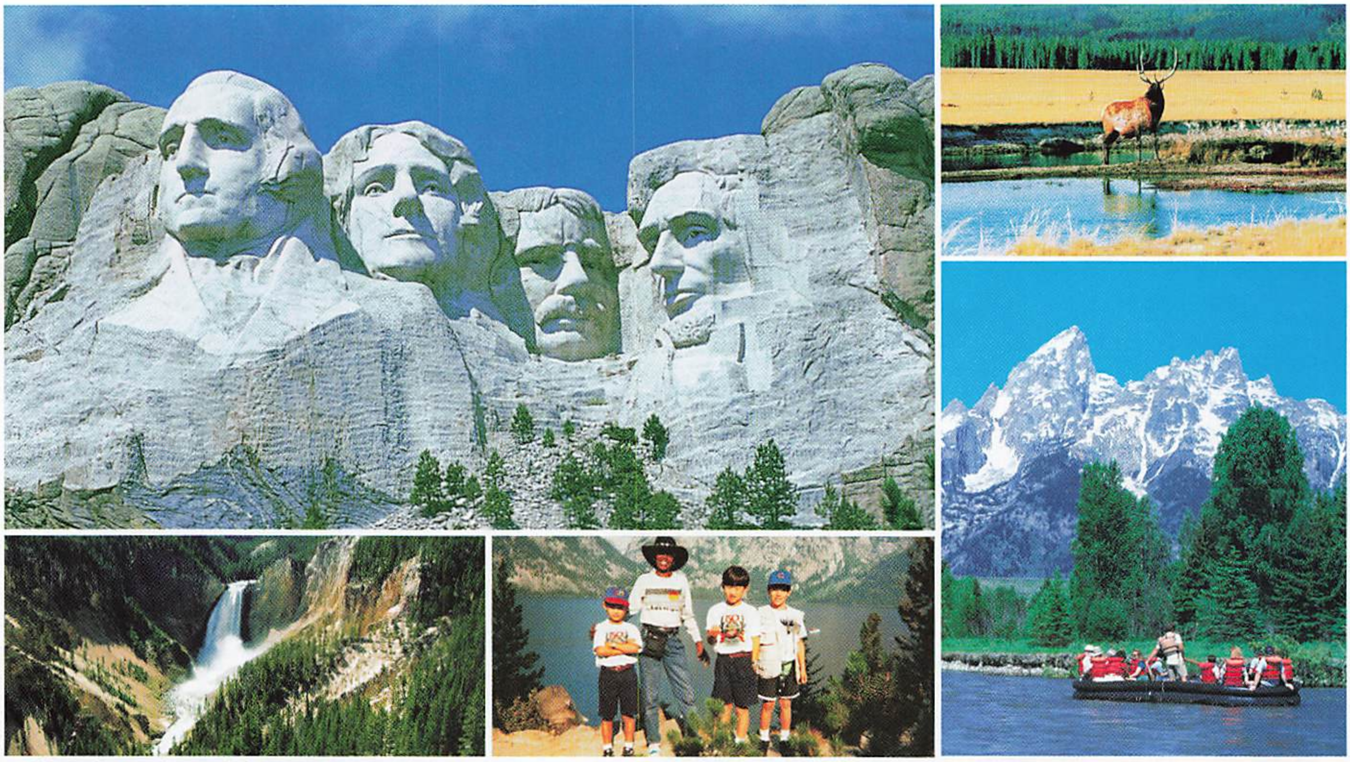

Clockwise starting top left: Mt. Rushmore, Yellowstone Park, floating on Snake River beneath the Grand Tetons, Jenny Lake, Yellowstone Falls

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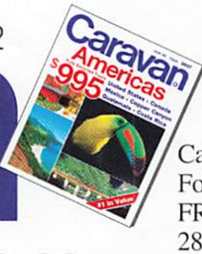

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contents

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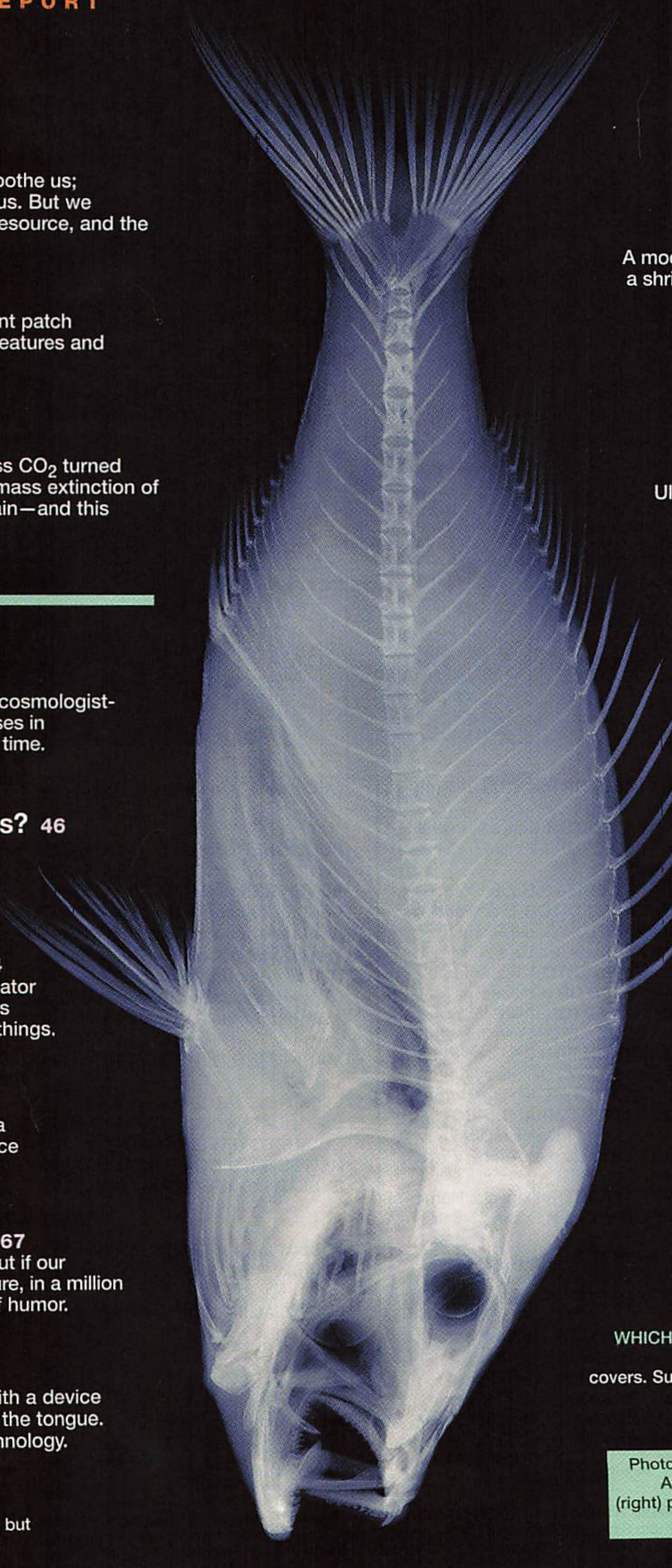


INVESTIGATIVE REPORT

What's Happening to Our Oceans

A Sea Change 23
The sounds of breaking waves soothe us; the contents of the seas sustain us. But we continue to abuse this precious resource, and the damage is adding up.

Better Planet 24
In the middle of the Pacific, a giant patch of garbage is endangering sea creatures and fouling the marine environment.
By Thomas M. Kostigen

Ocean Reflux 28
Some 55 million years ago, excess CO_2 turned the oceans acidic and caused a mass extinction of sea life. It is about to happen again—and this time the damage will be worse.
By Kathleen McAuliffe

DISCOVER Interview: Max Tegmark 38
Welcome to his worlds: The MIT cosmologist-philosopher posits parallel universes in multiple dimensions of space and time.
By Adam Frank

Medicine's Magic Bullets? 46
When a "wonder drug" falls short of expectations—or even does harm—who is to blame?
By Jeanne Lenzer

Pondering a Parasite 54
The author sees a backyard predator beset his red cedar and considers the interdependence of all living things.
By Gordon Grice

The Mummy Diaries 58
Ancient burial sites in central Asia are yielding secrets about the fierce warrior-nomads who lived there.
By Andrew Curry

Why Laughing Matters 67
The Internet may come and go, but if our primate past is a guide to the future, in a million years we will still have a sense of humor.
By Jim Holt

Sight Lines 74
The blind could one day "see" with a device that sends electrical impulses to the tongue. A sightless climber tests the technology.
By Buddy Levy

The barracuda looks fine in this X-ray, but are its days numbered? See page 23.

NICK VEASY/GETTY IMAGES

Contributors 4

Letters 7

Data 8
A moon's rings, the world's largest laser, a shrimp's strange eyes, the genetics of obesity, and more.

Vital Signs 18
A child has a seizure—and her doctor must think fast.
By Mark Cohen

Think Tech 20
Ultracapacitors: the next step in the evolution of the automobile.
By Stephen Cass

Reviews 70
Appreciating Buckminster Fuller, your dog's IQ, the illogic of fear, the science of snooping, and more.

Mind Games 76
Chess challenges from a school program promoting mental agility.
By Scott Kim

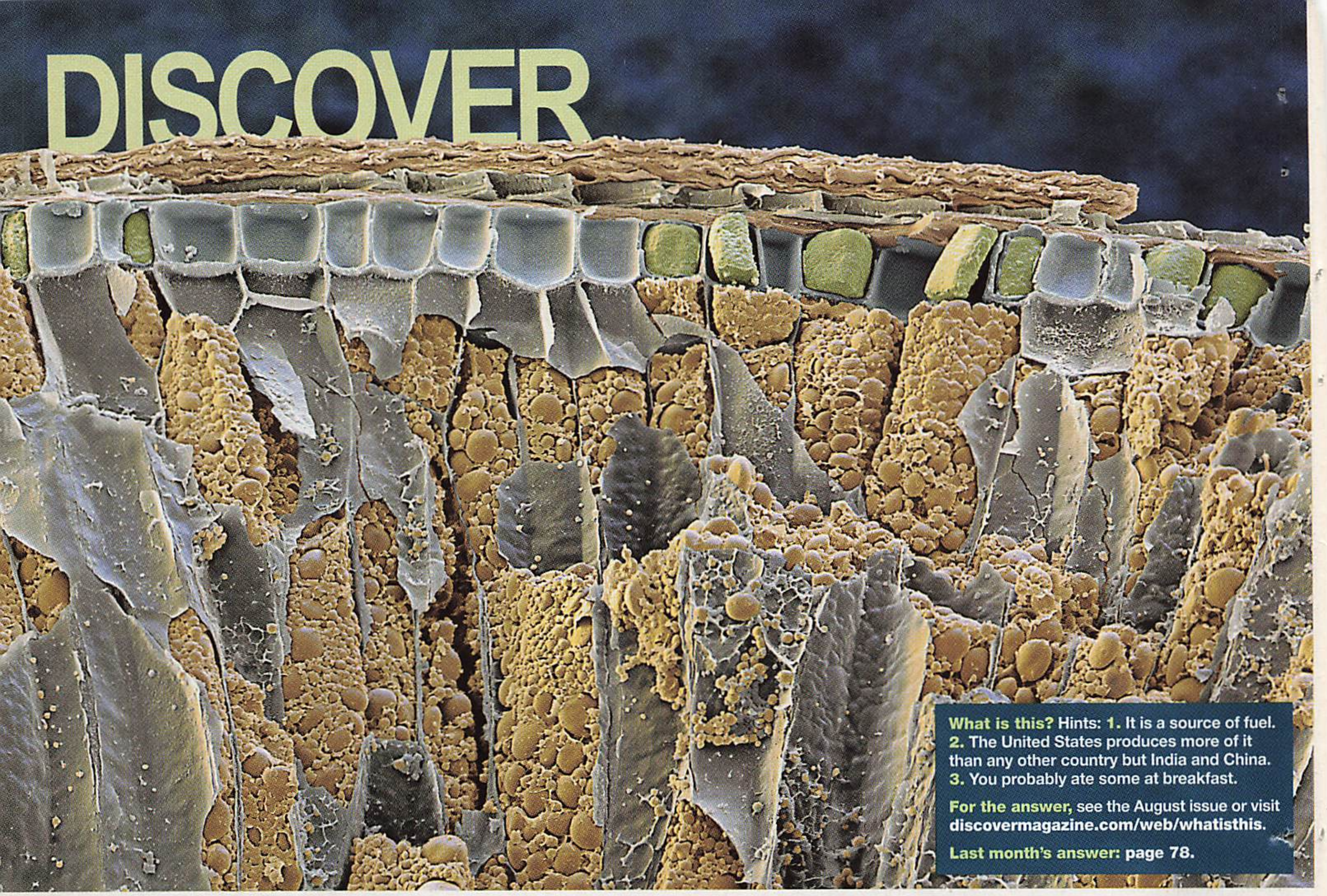
20 Things You Didn't Know About Oil 80
Saving at the pump.
By Susan Kruglinski

On the Covers

WHICH DO YOU LIKE BETTER? This month's issue was printed with two different covers. Subscribers received the one on the left; newsstands the one on the right. Vote at www.discovermagazine.com.

Photo illustration (left) by Richard Hernandez, Atomic Pencil Studio. Sunflower sea star (right) photographed by Paul Nicklen/National Geographc Image Collection.

DISCOVER



What is this? Hints: **1.** It is a source of fuel. **2.** The United States produces more of it than any other country but India and China. **3.** You probably ate some at breakfast.

For the answer, see the August issue or visit **discovermagazine.com/web/whatisthis.**

Last month's answer: page 78.

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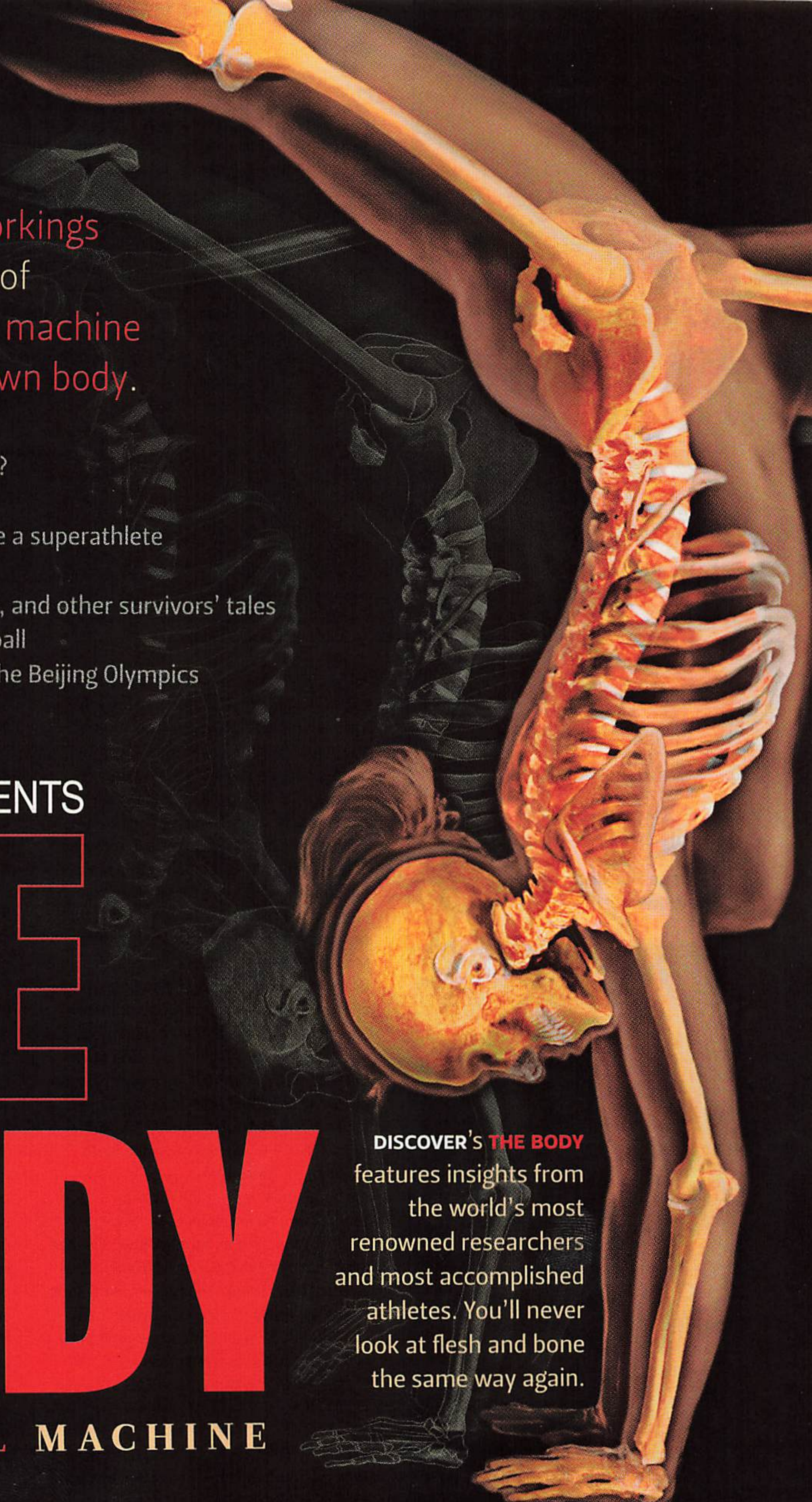

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- 22,000 feet without a chute, and other survivors' tales
- Secrets of a human cannonball
- A science insider's guide to the Beijing Olympics

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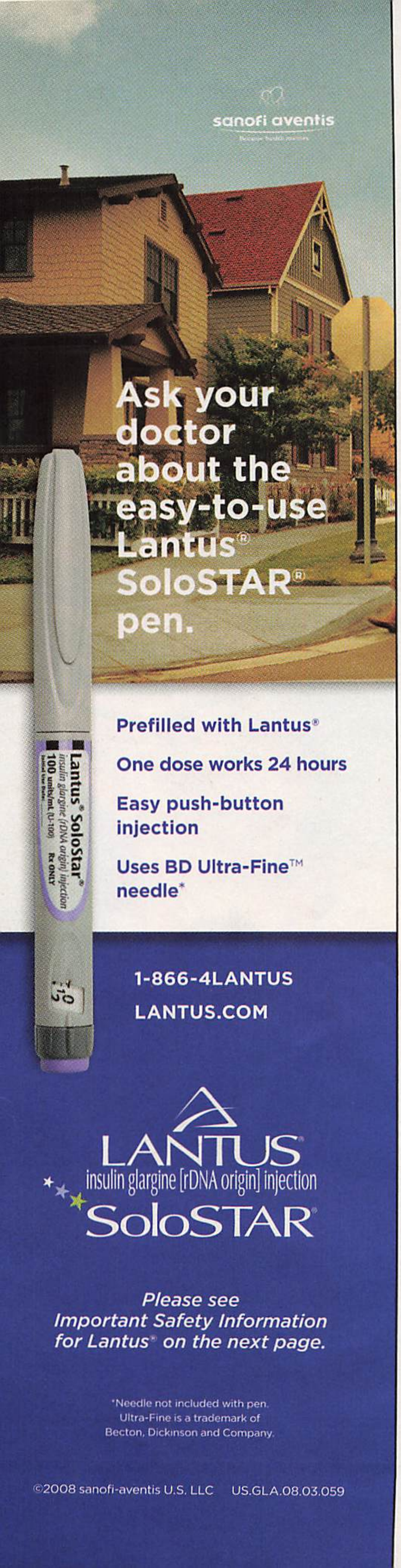
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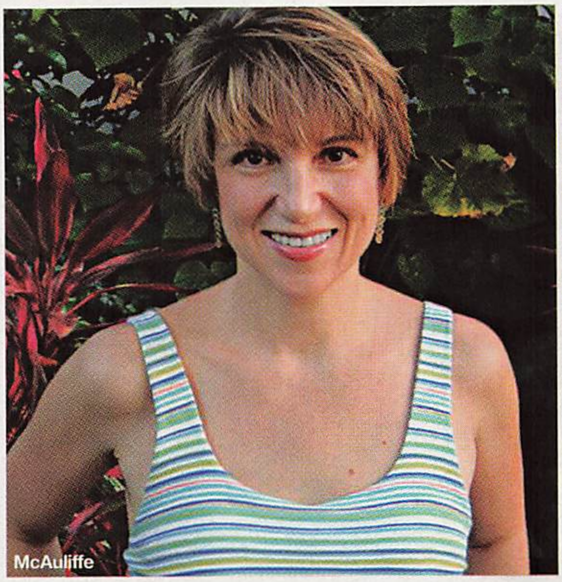
McAuliffe

Grice

Kim

KATHLEEN McAULIFFE ("Ocean Reflux," *page 28*), a Miami-based journalist, covers the biological sciences. This month she investigates how excess CO_2 in the atmosphere causes oceans to become more acidic. The result: higher ocean temperatures, which adversely affect marine life. The article had its genesis in a dinner conversation McAuliffe had with a marine biologist friend and his family. The biologist had just learned about ocean acidification at a conference. "He was clearly shaken," McAuliffe says. "He chose his words carefully when speaking about it in front of his children." She began to ask other marine biologists what they thought, and most told her they considered the increasing acidity of the ocean an "immediate threat." Ocean acidification provides an accurate timetable for when "disaster will unfold," McAuliffe says. "Give it 50 years before the reefs disintegrate." McAuliffe has seen firsthand the coral reefs' decline over the past 15 years on snorkeling trips to the Florida Keys. Although other factors have played a role, ocean acidification is "a major stress on an already fragile ecosystem," she says. "I wonder how I'm going to explain to my children in 20 years why my generation did nothing." McAuliffe has written for *Smithsonian, Atlantic Monthly,* and *U.S. News & World Report.*

GORDON GRICE ("Pondering a Parasite," *page 54*) is an award-winning writer based in Wisconsin. His essay in this issue is filled with poetic reflections and observations about an Eastern red cedar in his backyard and the fungus threatening its life. "You don't have to drive to a national park if you want to see nature. It's all around you if you look close enough," Grice says. While walking in his one-acre backyard with his oldest son, he noticed cedar-apple rust growing on the tree; it looked like "a half-frozen firework explosion of beautiful blossoms of fungus." The good news: Grice reports that pruning and patience have recently returned the tree to health. Grice has written a book about dangerous animals, *Deadly Kingdom,* due from Dial Press in 2009. His work has appeared in *Harper's, GQ, Granta,* and *The New Yorker.*

SCOTT KIM has been creating original puzzles for his monthly Mind Games column (*page 76*) for nine years. Lately he has been revisiting classic puzzles and giving them a twist. Kim says variety is important, as is topicality. "I approach puzzles the same way Garry Trudeau approaches *Doonesbury,*" Kim says. "A lot of my puzzles tell readers about things that are happening in the world." It takes Kim a week to create a puzzle for DISCOVER, including research, writing, and illustration. "If you are interested in sending me puzzle ideas, you can contact me at scott@shufflebrain.com," he says. **Boonsri Dickinson**

MCAULIFFE: JOSHUA COHN; GRICE: TRACY HIATT GRICE; KIM: STEVE SAVAGE

Sandy can stop traffic; she also has type 2 diabetes. Some people take two insulin shots a day to get 24-hour blood sugar control. But Sandy takes one shot of Lantus®, the only 24-hour insulin approved exclusively for use once a day. Lantus® works steadily all day with no pronounced peak, so you don't have to eat at a specific time to balance a peak. And as part of your overall diabetes treatment plan, including regular blood sugar testing, just one shot of Lantus® at the same time each day helps control blood sugar all day long.

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Prescription Lantus® is for adults with type 2 diabetes or adults and children (6 years and older) with type 1 diabetes who require long-acting insulin for the control of high blood sugar.

Lantus® SoloStar® is a disposable insulin delivery device (insulin pen). **Needles and the SoloStar® pen must not be shared.**

DO NOT DILUTE OR MIX LANTUS® WITH ANY OTHER INSULIN OR SOLUTION. It will not work as intended, and you may lose blood sugar control, which could be serious. Do not change your insulin without talking with your doctor. The syringe must not contain any other medication or residue. You should not use Lantus® if you are allergic to insulin. Lantus® is a long-acting insulin you inject just once a day, at the same time each day. **You must test your blood sugar levels while using an insulin such as Lantus®.**

The most common side effect of insulin, including Lantus®, is hypoglycemia, which may be serious. Other possible side effects may include injection site reactions, including changes in fat tissue at the injection site, and allergic reactions, including itching and rash. In rare cases, some allergic reactions may be life threatening. Tell your doctor about other medicines and supplements you are taking because they can change the way insulin works.

Please see additional important information on the next page.

You are encouraged to report negative side effects of prescription drugs to the FDA. Visit www.fda.gov/medwatch, or call 1-800-FDA-1088.

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Ask your doctor if Lantus® fits into your overall diabetes treatment plan, which includes diet, exercise, and other diabetes medications.

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*Based on TRx data from IMS Health, National Prescription Audit Plus™ (new methodology), May 2003–December 2007.

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Brief Summary of Prescribing Information April 2006 **Rx Only**

LANTUS®

(insulin glargine [rDNA origin] injection)

LANTUS® must NOT be diluted or mixed with any other insulin or solution.

INDICATIONS AND USAGE

LANTUS is indicated for once-daily subcutaneous administration for the treatment of adult and pediatric patients with type 1 diabetes mellitus or adult patients with type 2 diabetes mellitus who require basal (long-acting) insulin for the control of hyperglycemia.

CONTRAINDICATIONS

LANTUS is contraindicated in patients hypersensitive to insulin glargine or the excipients.

WARNINGS

Hypoglycemia is the most common adverse effect of insulin, including LANTUS. As with all insulins, the timing of hypoglycemia may differ among various insulin formulations. Glucose monitoring is recommended for all patients with diabetes.

Any change of insulin should be made cautiously and only under medical supervision. Changes in insulin strength, timing of dosing, manufacturer, type (e.g., regular, NPH, or insulin analogs), species (animal, human), or method of manufacture (recombinant DNA versus animal-source insulin) may result in the need for a change in dosage. Concomitant oral antidiabetes treatment may need to be adjusted.

PRECAUTIONS

General:

LANTUS is not intended for intravenous administration. The prolonged duration of activity of insulin glargine is dependent on injection into subcutaneous tissue. Intravenous administration of the usual subcutaneous dose could result in severe hypoglycemia.

LANTUS must NOT be diluted or mixed with any other insulin or solution. If LANTUS is diluted or mixed, the solution may become cloudy, and the pharmacokinetic/pharmacodynamic profile (e.g., onset of action, time to peak effect) of LANTUS and/or the mixed insulin may be altered in an unpredictable manner. When LANTUS and regular human insulin were mixed immediately before injection in dogs, a delayed onset of action and time to maximum effect for regular human insulin was observed. The total bioavailability of the mixture was also slightly decreased compared to separate injections of LANTUS and regular human insulin. The relevance of these observations in dogs to humans is not known.

As with all insulin preparations, the time course of LANTUS action may vary in different individuals or at different times in the same individual and the rate of absorption is dependent on blood supply, temperature, and physical activity.

Insulin may cause sodium retention and edema, particularly if previously poor metabolic control is improved by intensified insulin therapy.

Hypoglycemia:

As with all insulin preparations, hypoglycemic reactions may be associated with the administration of LANTUS. Hypoglycemia is the most common adverse effect of insulins. Early warning symptoms of hypoglycemia may be different or less pronounced under certain conditions, such as long duration of diabetes, diabetes nerve disease, use of medications such as beta-blockers, or intensified diabetes control (see PRECAUTIONS, Drug Interactions). Such situations may result in severe hypoglycemia (and, possibly, loss of consciousness) prior to patients' awareness of hypoglycemia.

The time of occurrence of hypoglycemia depends on the action profile of the insulins used and may, therefore, change when the treatment regimen or timing of dosing is changed. Patients being switched from twice daily NPH insulin to once-daily LANTUS should have their initial LANTUS dose reduced by 20% from the previous total daily NPH dose to reduce the risk of hypoglycemia (see DOSAGE AND ADMINISTRATION, Changeover to LANTUS).

The prolonged effect of subcutaneous LANTUS may delay recovery from hypoglycemia.

In a clinical study, symptoms of hypoglycemia or counterregulatory hormone responses were similar after intravenous insulin glargine and regular human insulin both in healthy subjects and patients with type 1 diabetes.

Renal Impairment:

Although studies have not been performed in patients with diabetes and renal impairment, LANTUS requirements may be diminished because of reduced insulin metabolism, similar to observations found with other insulins (see CLINICAL PHARMACOLOGY, Special Populations).

Hepatic Impairment:

Although studies have not been performed in patients with diabetes and hepatic impairment, LANTUS requirements may be diminished due to reduced capacity for gluconeogenesis and reduced insulin metabolism, similar to observations found with other insulins (see CLINICAL PHARMACOLOGY, Special Populations).

Injection Site and Allergic Reactions:

As with any insulin therapy, lipodystrophy may occur at the injection site and delay insulin absorption. Other injection site reactions with insulin therapy include redness, pain, itching, hives, swelling, and inflammation. Continuous rotation of the injection site within a given area may help to reduce or prevent these reactions. Most minor reactions to insulins usually resolve in a few days to a few weeks.

Reports of injection site pain were more frequent with LANTUS than NPH human insulin (2.7% insulin glargine versus 0.7% NPH). The reports of pain at the injection site were usually mild and did not result in discontinuation of therapy.

Immediate-type allergic reactions are rare. Such reactions to insulin (including insulin glargine) or the excipients may, for example, be associated with generalized skin reactions, angioedema, bronchospasm, hypotension, or shock and may be life threatening.

Intercurrent Conditions:

Insulin requirements may be altered during intercurrent conditions such as illness, emotional disturbances, or stress.

Information for Patients:

LANTUS must only be used if the solution is clear and colorless with no particles visible (see DOSAGE AND ADMINISTRATION, Preparation and Handling).

Patients must be advised that LANTUS must NOT be diluted or mixed with any other insulin or solution (see PRECAUTIONS, General).

Patients should be instructed on self-management procedures including glucose monitoring, proper injection technique, and hypoglycemia and hyperglycemia management. Patients must be instructed on handling of special situations such as intercurrent conditions (illness, stress, or emotional disturbances), an inadequate or skipped insulin dose, inadvertent administration of an increased insulin dose, inadequate food intake, or skipped meals. Refer patients to the LANTUS "Patient Information" circular for additional information.

As with all patients who have diabetes, the ability to concentrate and/or react may be impaired as a result of hypoglycemia or hyperglycemia.

Patients with diabetes should be advised to inform their health care professional if they are pregnant or are contemplating pregnancy.

Drug Interactions:

A number of substances affect glucose metabolism and may require insulin dose adjustment and particularly close monitoring.

The following are examples of substances that may increase the blood-glucose-lowering effect and susceptibility to hypoglycemia: oral antidiabetes products, ACE inhibitors, disopyramide, fibrates, fluoxetine, MAO inhibitors, propoxyphene, salicylates, somatostatin analog (e.g., octreotide), sulfonamide antibiotics.

The following are examples of substances that may reduce the blood-glucose-lowering effect of insulin: corticosteroids, danazol, diuretics, sympathomimetic agents (e.g., epinephrine, albuterol, terbutaline), isoniazid, phenothiazine derivatives, somatropin, thyroid hormones, estrogens, progestogens (e.g., in oral contraceptives), protease inhibitors and atypical antipsychotic medications (e.g. olanzapine and clozapine).

Beta-blockers, clonidine, lithium salts, and alcohol may either potentiate or weaken the blood-glucose-lowering effect of insulin. Pentamidine may cause hypoglycemia, which may sometimes be followed by hyperglycemia.

In addition, under the influence of sympatholytic medicinal products such as beta-blockers, clonidine, guanethidine, and reserpine, the signs of hypoglycemia may be reduced or absent.

Carcinogenesis, Mutagenesis, Impairment of Fertility:

In mice and rats, standard two-year carcinogenicity studies with insulin glargine were performed at doses up to 0.455 mg/kg, which is for the rat approximately 10 times and for the mouse approximately 5 times the recommended human subcutaneous starting dose of 10 IU (0.008 mg/kg/day), based on mg/m^2. The findings in female mice were not conclusive due to excessive mortality in all dose groups during the study. Histiocytomas were found at injection sites in male rats (statistically significant) and male mice (not statistically significant) in acid vehicle containing groups. These tumors were not found in female animals, in saline control, or insulin comparator groups using a different vehicle. The relevance of these findings to humans is unknown.

Insulin glargine was not mutagenic in tests for detection of gene mutations in bacteria and mammalian cells (Ames- and HGPRT-test) and in tests for detection of chromosomal aberrations (cytogenetics in vitro in V79 cells and in vivo in Chinese hamsters).

In a combined fertility and prenatal and postnatal study in male and female rats at subcutaneous doses up to 0.36 mg/kg/day, which is approximately 7 times the recommended human subcutaneous starting dose of 10 IU (0.008 mg/kg/day), based on mg/m^2, maternal toxicity due to dose-dependent hypoglycemia, including some deaths, was observed. Consequently, a reduction of the rearing rate occurred in the high-dose group only. Similar effects were observed with NPH human insulin.

Pregnancy:

Teratogenic Effects: Pregnancy Category C. Subcutaneous reproduction and teratology studies have been performed with insulin glargine and regular human insulin in rats and Himalayan rabbits. The drug was given to female rats before mating, during mating, and throughout pregnancy at doses up to 0.36 mg/kg/day, which is approximately 7 times the recommended human subcutaneous starting dose of 10 IU (0.008 mg/kg/day), based on mg/m^2. In rabbits, doses of 0.072 mg/kg/day, which is approximately 2 times the recommended human subcutaneous starting dose of 10 IU (0.008 mg/kg/day), based on mg/m^2, were administered during organogenesis. The effects of insulin glargine did not generally differ from those observed with regular human insulin in rats or rabbits. However, in rabbits, five fetuses from two litters of the high-dose group exhibited dilation of the cerebral ventricles. Fertility and early embryonic development appeared normal.

There are no well-controlled clinical studies of the use of insulin glargine in pregnant women. It is essential for patients with diabetes or a history of gestational diabetes to maintain good metabolic control before conception and throughout pregnancy. Insulin requirements may decrease during the first trimester, generally increase during the second and third trimesters, and rapidly decline after delivery. Careful monitoring of glucose control is essential in such patients. Because animal reproduction studies are not always predictive of human response, this drug should be used during pregnancy only if clearly needed.

Nursing Mothers:

It is unknown whether insulin glargine is excreted in significant amounts in human milk. Many drugs, including human insulin, are excreted in human milk. For this reason, caution should be exercised when LANTUS is administered to a nursing woman. Lactating women may require adjustments in insulin dose and diet.

Pediatric Use:

Safety and effectiveness of LANTUS have been established in the age group 6 to 15 years with type 1 diabetes.

Geriatric Use:

In controlled clinical studies comparing insulin glargine to NPH human insulin, 593 of 3890 patients with type 1 and type 2 diabetes were 65 years and older. The only difference in safety or effectiveness in this subpopulation compared to the entire study population was an expected higher incidence of cardiovascular events in both insulin glargine and NPH human insulin-treated patients.

In elderly patients with diabetes, the initial dosing, dose increments, and maintenance dosage should be conservative to avoid hypoglycemic reactions. Hypoglycemia may be difficult to recognize in the elderly (see PRECAUTIONS, Hypoglycemia).

ADVERSE REACTIONS

The adverse events commonly associated with LANTUS include the following:

Body as a whole: allergic reactions (see PRECAUTIONS).

Skin and appendages: injection site reaction, lipodystrophy, pruritus, rash (see PRECAUTIONS).

Other: hypoglycemia (see WARNINGS and PRECAUTIONS).

In clinical studies in adult patients, there was a higher incidence of treatment-emergent injection site pain in LANTUS-treated patients (2.7%) compared to NPH insulin-treated patients (0.7%). The reports of pain at the injection site were usually mild and did not result in discontinuation of therapy. Other treatment-emergent injection site reactions occurred at similar incidences with both insulin glargine and NPH human insulin.

Retinopathy was evaluated in the clinical studies by means of retinal adverse events reported and fundus photography. The numbers of retinal adverse events reported for LANTUS and NPH treatment groups were similar for patients with type 1 and type 2 diabetes. Progression of retinopathy was investigated by fundus photography using a grading protocol derived from the Early Treatment Diabetic Retinopathy Study (ETDRS). In one clinical study involving patients with type 2 diabetes, a difference in the number of subjects with ≥3-step progression in ETDRS scale over a 6-month period was noted by fundus photography (7.5% in LANTUS group versus 2.7% in NPH treated group). The overall relevance of this isolated finding cannot be determined due to the small number of patients involved, the short follow-up period, and the fact that this finding was not observed in other clinical studies.

OVERDOSAGE

An excess of insulin relative to food intake, energy expenditure, or both may lead to severe and sometimes long-term and life-threatening hypoglycemia. Mild episodes of hypoglycemia can usually be treated with oral carbohydrates. Adjustments in drug dosage, meal patterns, or exercise may be needed.

More severe episodes with coma, seizure, or neurologic impairment may be treated with intramuscular/subcutaneous glucagon or concentrated intravenous glucose. After apparent clinical recovery from hypoglycemia, continued observation and additional carbohydrate intake may be necessary to avoid reoccurrence of hypoglycemia.

DOSAGE AND ADMINISTRATION

LANTUS is a recombinant human insulin analog. Its potency is approximately the same as human insulin. It exhibits a relatively constant glucose-lowering profile over 24 hours that permits once-daily dosing.

LANTUS may be administered at any time during the day. LANTUS should be administered subcutaneously once a day at the same time every day. For patients adjusting timing of dosing with LANTUS, see **WARNINGS** and **PRECAUTIONS, Hypoglycemia.** LANTUS is not intended for intravenous administration (see PRECAUTIONS). Intravenous administration of the usual subcutaneous dose could result in severe hypoglycemia. The desired blood glucose levels as well as the doses and timing of antidiabetes medications must be determined individually. Blood glucose monitoring is recommended for all patients with diabetes. The prolonged duration of activity of LANTUS is dependent on injection into subcutaneous space.

As with all insulins, injection sites within an injection area (abdomen, thigh, or deltoid) must be rotated from one injection to the next.

In clinical studies, there was no relevant difference in insulin glargine absorption after abdominal, deltoid, or thigh subcutaneous administration. As for all insulins, the rate of absorption, and consequently the onset and duration of action, may be affected by exercise and other variables.

LANTUS is not the insulin of choice for the treatment of diabetes ketoacidosis. Intravenous short-acting insulin is the preferred treatment.

Pediatric Use:

LANTUS can be safely administered to pediatric patients ≥6 years of age. Administration to pediatric patients <6 years has not been studied. Based on the results of a study in pediatric patients, the dose recommendation for changeover to LANTUS is the same as described for adults in DOSAGE AND ADMINISTRATION, Changeover to LANTUS.

Initiation of LANTUS Therapy:

In a clinical study with insulin naïve patients with type 2 diabetes already treated with oral antidiabetes drugs, LANTUS was started at an average dose of 10 IU once daily, and subsequently adjusted according to the patient's need to a total daily dose ranging from 2 to 100 IU.

Changeover to LANTUS:

If changing from a treatment regimen with an intermediate- or long-acting insulin to a regimen with LANTUS, the amount and timing of short-acting insulin or fast-acting insulin analog or the dose of any oral antidiabetes drug may need to be adjusted. In clinical studies, when patients were transferred from once-daily NPH human insulin or ultralente human insulin to once-daily LANTUS, the initial dose was usually not changed. However, when patients were transferred from twice-daily NPH human insulin to LANTUS once daily, to reduce the risk of hypoglycemia, the initial dose (IU) was usually reduced by approximately 20% (compared to total daily IU of NPH human insulin) and then adjusted based on patient response (see PRECAUTIONS, Hypoglycemia).

A program of close metabolic monitoring under medical supervision is recommended during transfer and in the initial weeks thereafter. The amount and timing of short-acting insulin or fast-acting insulin analog may need to be adjusted. This is particularly true for patients with acquired antibodies to human insulin needing high-insulin doses and occurs with all insulin analogs. Dose adjustment of LANTUS and other insulins or oral antidiabetes drugs may be required; for example, if the patient's timing of dosing, weight or lifestyle changes, or other circumstances arise that increase susceptibility to hypoglycemia or hyperglycemia (see PRECAUTIONS, Hypoglycemia).

The dose may also have to be adjusted during intercurrent illness (see PRECAUTIONS, Intercurrent Conditions).

Brief Summary of Prescribing Information April 2006

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Bridgewater, NJ 08807

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MAIL

Healing the Planet

Thank you so much for your Better Planet issue [May]. I was so depressed about the greenhouse effect that I feared reading any science magazine. Your positive take on how to heal the earth was beautiful. It will take time, but there is hope, and your articles made me more determined to help.

Kristine Knapp Wilmington, OH

"The Next Step" [May] provides good ideas that our leaders and legislators should take seriously. The elephant in the room is population growth. In my lifetime, world population has tripled. We need to start putting on the brakes. It seems better to limit population than to let it grow unchecked, only to have our numbers drastically reduced by starvation, disease, poisoning, and catastrophe.

Bill Peterson Champaign, IL

I applaud and thank you for your Better Planet issue. Our high-energy lifestyle is not sustainable on a global scale. It is unrealistic to pretend that it is. Science must develop a safe energy source for all people while educating us all to "need" less.

Gail Stumpf Nsentip Fort Bragg, CA

A Nuclear Comeback

I and other engineers and scientists who have been in favor of nuclear power for 30 years took a lot of abuse from environmentalists. Many of them now realize that nuclear power isn't the devil they said it was ["Better Energy," May]. In fact, they are using the same arguments in its favor that we used decades ago. Maybe if we had ignored their protestations, the climate would be in much better shape.

Tim Thompson Colorado Springs, CO

Nuclear power is, in the short term, a necessary step. It is not a long-term solution. We do have a method of generating power with a minimal footprint, which our government and most scientists have long ignored: space-based solar. Solar collectors in orbit can beam energy to the earth. Had we started building these in the 1970s when they were first proven feasible, we might already be producing power without fossil fuels. If we do not act quickly, we will run out of time.

Charles M. Barnard Menomonie, WI

BETTER PLANET SPECIAL ISSUE
DISCOVER
Science, Technology, and The Future
How Science Will Heal The Earth
THE DARING PLAN TO RECLAIM WATER
THE FOOD WITH NO FOOTPRINT
A CHEAP FIX THAT CLEARS THE AIR
GO CARBON NEUTRAL (WE DID)
THE BIODIVERSITY TRADE-OFF
OUR ONLY REAL ENERGY CHOICE
TACKLING PLASTICS' TOXIC HEALTH THREAT
PLUS
Watch Supernovas in Real Time, Visit Hog Hell, Return to the Moon, and Store Your Life on a Disk

Sure, if we wonder, "How can we preserve our incredibly wasteful lifestyle?" we will turn to measures such as nuclear energy. But it is hard to take this seriously from a country that won't even impose meaningful fuel efficiency standards on vehicles. The raw material for nuclear energy causes cancer in those who mine it. It renders the surrounding areas unusable and leaches radioactive products into streams and groundwater. Yet we have the hubris to believe that we can safely store the toxic waste created for hundreds of thousands of years. I can't help thinking that if nuclear power is the answer, we must be asking the wrong question.

Tim Goncharoff Santa Cruz, CA

Hold the Crickets

We are all trying to find a way to reduce our footprint, but let's put insects in perspective ["Better Food," May]. A person would need to eat about one pound of insects per day to meet daily protein needs. If half of the adult U.S. population did this, they would eat more than 100 million pounds of insects per day, nearly 40 billion pounds per year. Even if insects are extremely efficient in converting food to growth, they would still generate billions of pounds of waste per year. And that does not even include the cricket parts we don't eat. Waste poses a challenge any time we try to scale up food systems for a big population.

Mary Beth Hall Madison, WI

On the Trail of Offsets

You recently calculated your carbon footprint with an eye to buying offsets for a carbon-neutral issue ["The Paper Trail," May]. I am curious about how the process of buying carbon offsets works and where the money goes. Has anyone followed this trail?

John Dickey Horsham, PA

Editor's note: We wondered the same thing. Keep an eye out for an article in an upcoming issue exploring the workings of the offset industry.

Universe Is Ready for Its Close-Up

Having participated in the feasibility design of the Hubble Space Telescope at the Goddard Space Flight Center, I was very excited to read about the Large Synoptic Survey Telescope ["Movie Camera to the Stars," May]. Its completion will be a fantastic astronomical advancement. If there is room for a designer on the team, I'm ready to come out of retirement.

Victor C. Orem Sebring, FL

Erratum

In April's Think Tech, silicon was mistakenly described as a metallic material. It should have been characterized as a metalloid.

Send e-mail to editorial@discovermagazine.com. Address letters to DISCOVER, 90 Fifth Avenue, NY, NY 10011. Include your full name, address, and daytime phone number.

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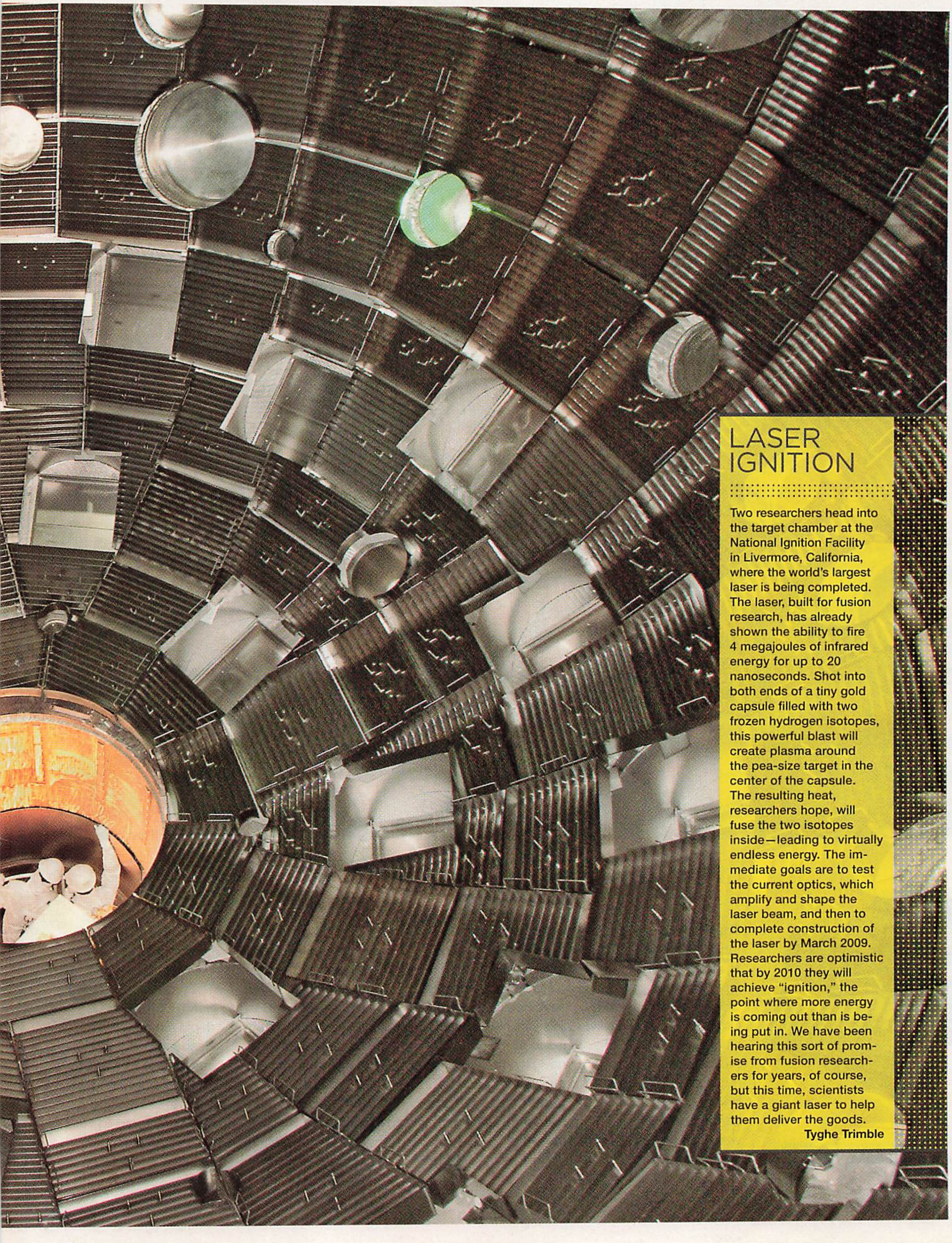


LASER IGNITION

Two researchers head into the target chamber at the National Ignition Facility in Livermore, California, where the world's largest laser is being completed. The laser, built for fusion research, has already shown the ability to fire 4 megajoules of infrared energy for up to 20 nanoseconds. Shot into both ends of a tiny gold capsule filled with two frozen hydrogen isotopes, this powerful blast will create plasma around the pea-size target in the center of the capsule. The resulting heat, researchers hope, will fuse the two isotopes inside—leading to virtually endless energy. The immediate goals are to test the current optics, which amplify and shape the laser beam, and then to complete construction of the laser by March 2009. Researchers are optimistic that by 2010 they will achieve "ignition," the point where more energy is coming out than is being put in. We have been hearing this sort of promise from fusion researchers for years, of course, but this time, scientists have a giant laser to help them deliver the goods.

Tyghe Trimble

SHRIMP'S-EYE VIEW

What does the world look like through the eyes of a mantis shrimp? It's not a question most of us would think to ask, but a new study has given us the answer: It looks like nothing humans (or any other animals) have ever seen.

It turns out that these exotic sea critters—affectionately known to the researchers in the study as "shrimp from Mars"—can see a kind of light that, as far as we know, is not apparent to any other animal on the planet. Not only that, but certain parts of the shrimps' bodies can reflect the same kind of light, creating a signal only other mantis shrimp can see. Thanks to this phenomenon, the creatures have their own visual code—a completely private way to communicate with one another as they scuttle across the ocean floor.

A research team well versed in the ways of mantis shrimp was tipped off by a set of unusual structures within the animals' eyes. These structures use the same principles as man-made detectors built to sense circularly polarized light—a specialized kind of light used to reduce the glare off computer monitors and take clearer photographs. When the researchers poked tiny electrodes into the shrimps' eyes and directed circularly polarized light onto them, they found that the same cells responded in different ways, at times recognizing the properties of circularly polarized light.

As for what one mantis shrimp looks like to another, Tom Cronin, a biologist at the University of Maryland Baltimore County and one of the study's authors, says that "it's impossible to know."

Jocelyn Rice

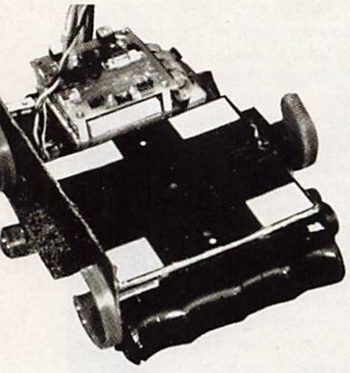
This mantis shrimp, *Odontodactylus scyllarus,* has a unique body language.

BEACH BOTS

The Mars rover Opportunity idled in a Martian sand dune for 39 long days, trapped with its wheels mostly covered. Only after very gradually working its way out of the sand could the rover move on. Given the long life of Opportunity, the temporary sand trap was not a grave concern, but other missions may not be as lucky. When we send more rovers to dusty terrain on Mars and the moon, sand could still cripple a mission. Now advances in robots capable of navigating waves of sand may make concerns of alien dust storms or sand traps a thing of the past.

Built at the University of Pennsylvania and tested at the Georgia Institute of Technology under team leader Daniel Goldman, SandBot is a six-legged robot with curved, C-shaped limbs instead of wheels. SandBot's limbs spin around like regular wheels but slow down briefly when they strike the ground, allowing it to scoot along loose sand at up to three centimeters per second. The technology behind SandBot will first be deployed on Earth in RespondBot, a search-and-rescue robot built to assist police and fire departments facing situations too risky for humans to enter.

Calla Cofield



For video of the SandBot in action, go to **www.discovermagazine.com/web/sandbot**

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PACKING A GUT, BUT WHO IS TO BLAME?

Obesity costs the American people nearly $75 billion each year.

The blame game for obesity (was it your parents or those cupcakes?) continues to escalate. Two recent studies—one in mice and another in humans—provide new evidence that a mind-numbingly complex array of genes influence body weight. By sampling fat tissue, one group of researchers found that the activity of 17,000 genes correlate with body mass index (a measure of body fat based on height and weight), and 14,900 correlate with waist-to-hip ratio. Complicating matters further, these genes seem to operate in large networks, interacting with each other and the environment to influence weight.

So should you blame genes—with labels like *Lpl, Lactb,* and *Ppm1l*—or fast food and failure to exercise for your weighty woes? The top researchers say they still don't know.

Data from identical twins going back as far as the 1930s suggest that body weight is at least partly inherited, but only in recent years have scientists begun to appreciate the complexity of the genetic factors underlying obesity. Robert Kushner, a specialist in obesity medicine at Northwestern University, says that identifying the interacting genes will help screen those at risk, but far more research is needed before pharmaceutical interventions might emerge.

And even then, no one thinks that genetic testing or manipulation will ever lead to a catch-all cure. George Bray, who heads the clinical obesity and metabolism department at Louisiana State University, says environment and behavior—like lack of access to exercise facilities and overeating—so strongly affect gene activity that you cannot focus on one while ignoring the other. Both experts agree that addressing energy balance—the number of calories consumed versus the number used in physical activity—is a good starting point for anyone struggling with obesity. Research continues, but holding out for a miracle weight-loss drug is probably not the answer. As Kushner puts it, "a magic bullet is highly unlikely." **Jennifer Barone**

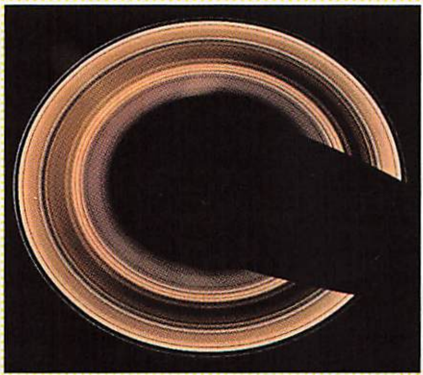
For eight diets from the nation's top doctors, go to **www.discovermagazine.com/web/yourweight.**

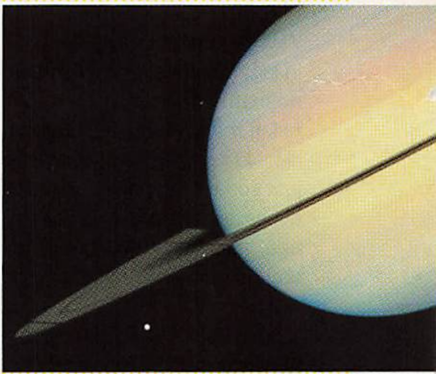
Ring Around a Moon

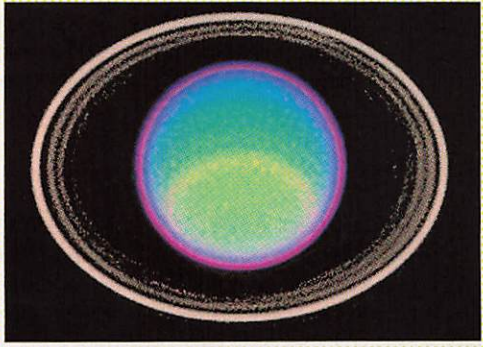
For more than 300 years we thought Saturn was the only body in the solar system with rings. But by 1989, after ground-based measurements and flybys from Voyagers 1 and 2, we had discovered rings around the other three gas giants—Jupiter, Uranus, and Neptune. Now the Cassini spacecraft appears to have found a ring system around Saturn's second-largest moon, Rhea. The discovery took astronomers by surprise. Just what is a ring doing around a moon, especially one that is significantly smaller than our own?

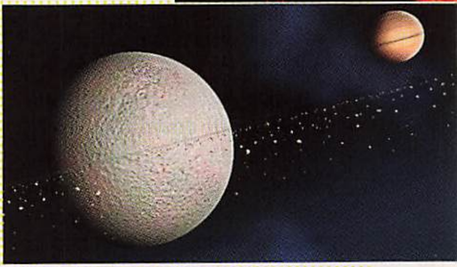
Normally a ring forms when two things are present: space debris, either from a collision with a small body or left over from the solar system's formation, and sufficient gravity to attract the debris and hold it in place. While the gas giants all have what it takes to hold a ring system in place, "a ring system around a moon comes as a surprise because the parent planet's gravity should destabilize any ring system that might form," says Richard P. Binzel, a professor of planetary science at MIT.

That leaves two possible explanations for Rhea's ring. It may be that the debris was kicked off recently enough that Saturn has not yet had a chance to destabilize it. But it is more likely that Rhea is uniquely suited to hold debris in orbit. Simulations indicate that, given Rhea's size and distant orbit around Saturn, this moon could potentially hang on to a ring for millions of years or more before the planet's pull overcomes Rhea's hold. Whatever the case, the mission scientists are eager to gather more data when Cassini returns to Rhea in 2010. **Patrick Huyghe**



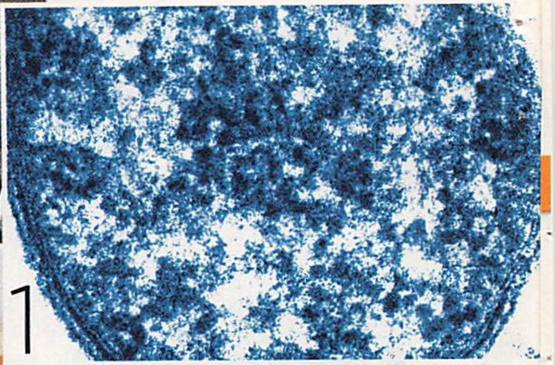


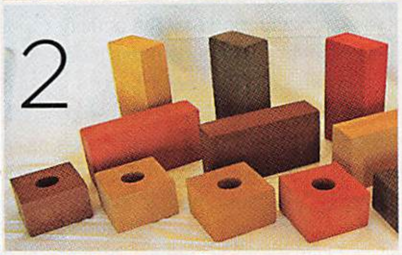




Big planets with rings—such as Uranus (left) and Saturn (above and right)—are familiar to astrophysicists, but if the moon Rhea (drawn below) has rings, researchers have new questions.

TOP: ILLUSTRATION BY J. SIERS. BOTTOM: NASA (5)





Tech Against Toxins

We bury them underground, drown them in lagoons, or shove them out to sea—no matter how remote a site, it may be full of the toxic by-products of modern life. Nuclear waste and heavy metals are just some of the noxious residue of our everyday existence. To reverse the damage, scientists turn to both innovative technologies and peculiar organisms.

CHLORINE CUISINE If they make their way into the groundwater, chlorinated wastes, like those found in dry-cleaning fluids and paint thinner, can cause liver problems and cancer in people. But some bacteria find these chemicals quite palatable: When *Dehalococcoides ethenogenes* **(1)** comes in contact with the chemicals, it feasts on chlorinated compounds, converting them into harmless gases.

FLY ASH BRICKS In the process of generating electricity, U.S. coal plants spew more than 70 million tons a year of a radioactive waste called fly ash. Now a Missouri company has found a way to turn the ash into bricks **(2)**, an innovation that reduces fly ash while providing an extra benefit: The bricks soak up toxic mercury from the air.

PURGING PESTICIDES White rot fungi **(3)**, common in the forests of North America, use special enzymes to convert the carbon in trees to energy. These same enzymes can oxidize environmental pollutants such as pesticides **(4)** and PCBs, rendering them benign.

FLUSHING IRON Metal toxins commonly found at mining sites could be treated with the stinky remains of human wastewater **(5)**. The human waste, rife with iron, would be especially useful if dumped at sites loaded with cadmium, lead, and arsenic. The iron would readily react with the other metals and keep them from dissolving into nearby groundwater.

PLUTONIUM PYRAMIDS Hematite, a shiny black mineral sometimes used to make jewelry, can soak up plutonium and uranium waste from nuclear plants **(6)**. Scientists recently found that hematite crystals placed in acid grow pyramid-like structures on their surface **(7)**. As the structures form, contaminants can settle into tiny pockets in the hematite crystal, where they could remain stable for hundreds of years.

Karen Rowan

THE TICK PATCH

With patients complaining that standard antibiotic treatment can leave lingering symptoms, Lyme disease has long been mired in controversy. Now a new, long-acting preparation of the antibiotic doxycycline may help prevent Lyme and another tickborne infection.

Researchers at New York Medical College (NYMC) had tried using doxycycline as a Lyme preventive, reporting that a single oral dose could block transmission 85 percent of the time. But immunologist Nordin Zeidner, chief of the Centers for Disease Control and Prevention's Vector-Host Laboratory in Fort Collins, Colorado, had doubts, and after retesting the technique found a success rate of just 20 to 30 percent in mice.

Zeidner thought the problem was the single oral dose of the antibiotic, so he asked a Fort Collins company, QLT, to develop a form of injectable doxy that could be sustained in the body for 19 days. Trying it on mice, Zeidner found that 100 percent were protected from Lyme as well as anaplasmosis. Now he plans to study the approach in humans and hopes to develop a doxy skin patch that will last for an entire tick season.

Gary Wormser, an author of the NYMC study, meanwhile, counters that single-dose doxy should be more effective in humans than in mice because it stays in our blood longer.

Pamela Weintraub

THIS PAGE, LEFT TO RIGHT FROM TOP: ROCA/SHUTTERSTOCK; DR. K. M. ROSSO/PACIFIC NORTHWEST NATIONAL LABORATORY; SCIENCE/X. MAYMÓ-GATELL, Y. T. CHIEN, J. M. GOSSETT, AND S. H. ZINDER; SAN FRANCISCO PUBLIC UTILITIES COMMISSION; FREIGHT PIPELINE COMPANY; RICHARD R. HANSEN/PHOTO RESEARCHERS; TOMVOLKFUNGI.NET. OPPOSITE: UNIVERSAL PICTURES/EVERETT COLLECTION

GOOD GREASE

Don't be too quick to judge the next time someone you know skips a shower—he or she may actually be clearing the air.

The dangerous pollutant ozone, it turns out, is destroyed by hair and body oils, an oddity revealed when researchers at Missouri University of Science and Technology compared washed and unwashed hair. Environmental engineer Glenn Morrison and physician Lakshmi Pandrangi found that dirty hair—generally awash in skin oil—consumed seven times more ozone on average than did clean hair. The explanation is strictly chemical: The oils covering our bodies contain double-bonded molecules, including triglycerides, fatty acids, and a substance called squalene, that latch onto the ozone (O_3), neutralizing it before we breathe it in.

But what seems like a terrific natural defense system may have some drawbacks. The same reactions that reduce ozone also create by-products, including the respiratory irritants formaldehyde and 4-oxopentanal. Researchers have yet to determine how damaging those chemicals are in the small amounts produced.

While much has been done to learn about air pollution and the effects of smog, less is known about the importance of the "microenvironments" that surround our bodies. We spend about 90 percent of our time indoors, where chemical interactions between the air, human skin, and other things are not well known. Morrison says that even small changes, such as the use of hair products, can alter the air we breathe in critical ways. "Each home or office has its own unique smog event every day," he says.

Sarah Bates

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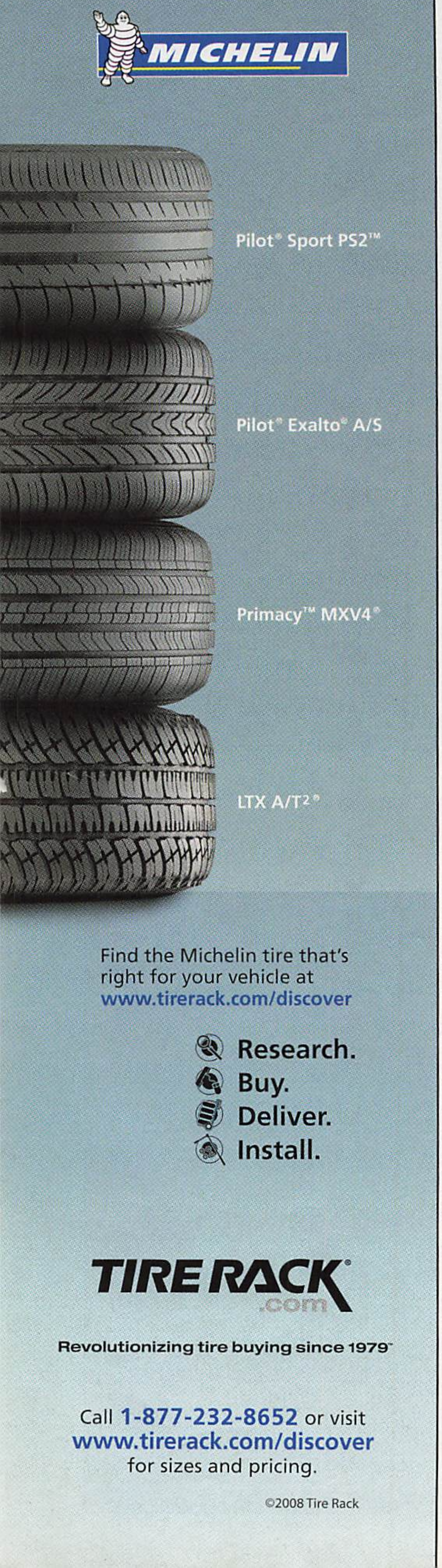

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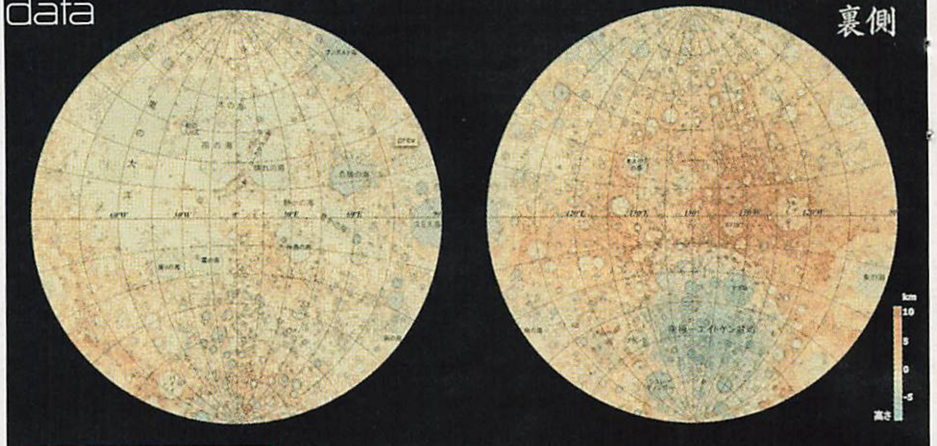

JAPAN MAPS THE MOON This chart may look like a guide for an ancient mariner, but it is actually a topographical map of the moon, created from data gathered by the Japan Aerospace Exploration Agency's Kayuga lunar orbiter and two satellites. Using a laser altimeter, Kayuga made more than 6 million measurements of the moon, including the previously unexplored polar regions.

For an in-depth look at the surface of the moon, including where humans have been and spots that may be well suited for human habitation, go to **www.discovermagazine.com/web/moonmap.**

SIREN SONGS

It is hard to avoid the female sex hormone estrogen and all the chemicals that mimic it: Not only do they show up in cosmetics and cleaning products, but they are also commonly used to make plastic bottles and line food cans. Some experts have traced estrogen-like chemicals to increased rates of human breast cancer, and there is even more evidence that they endanger animals by feminizing the sex organs of male frogs and fish living downstream from sewage treatment plants. Then there is one species of bird—the starling—in which environmental estrogens have an especially surprising effect: Exposed male starlings turn into better singers, duping female starlings into choosing mates that may be bad bets.

The discovery comes from Cardiff University in Wales, where researchers compared starlings raised in aviaries and fed a controlled diet with those living at sewage treatment plants and feasting on earthworms inhabiting the rocky filter beds. Since the worms survive on microbes that degrade the sewage, the treatment-plant starlings consumed natural human estrogen along with three estrogen mimics: DEHP, used to manufacture polyvinyl chloride; DBP, found in nail polish; and bisphenol A, common in hard plastic bottles.

At first, both groups of starlings appeared to behave normally, exhibiting a natural seasonal cycle in which "the whole [brain] mechanism for song shuts down in autumn, presumably to make room for other centers that are more important—like finding food," says Katherine Buchanan, a study leader. When the spring mating season rolled around, estrogen in the male brain surged in both groups, triggering an expansion of the vocal center and a burst of song. But for birds consuming the estrogen cocktail, the vocal center grew even larger—and they sang five times as long as uncontaminated birds and composed more complex songs. In the lab, female starlings showed a preference for those songs, perching near a loudspeaker that was playing them.

Blood tests, however, showed that the doped male starlings had compromised immune systems, suggesting that they were less fit. The starling population in Britain has dropped by half in the last four decades, Buchanan says, mostly because humans have been encroaching on their habitat—but perhaps also because pollutants are creating a siren song that has bewitched the females, luring them to reproduce with more musical, but less healthy, mates. **Robert Kunzig**

TOP: NAOJ/GSI/JAXA. BOTTOM: JUNIORS BILDARCHIV/AGEFOTOSTOCK

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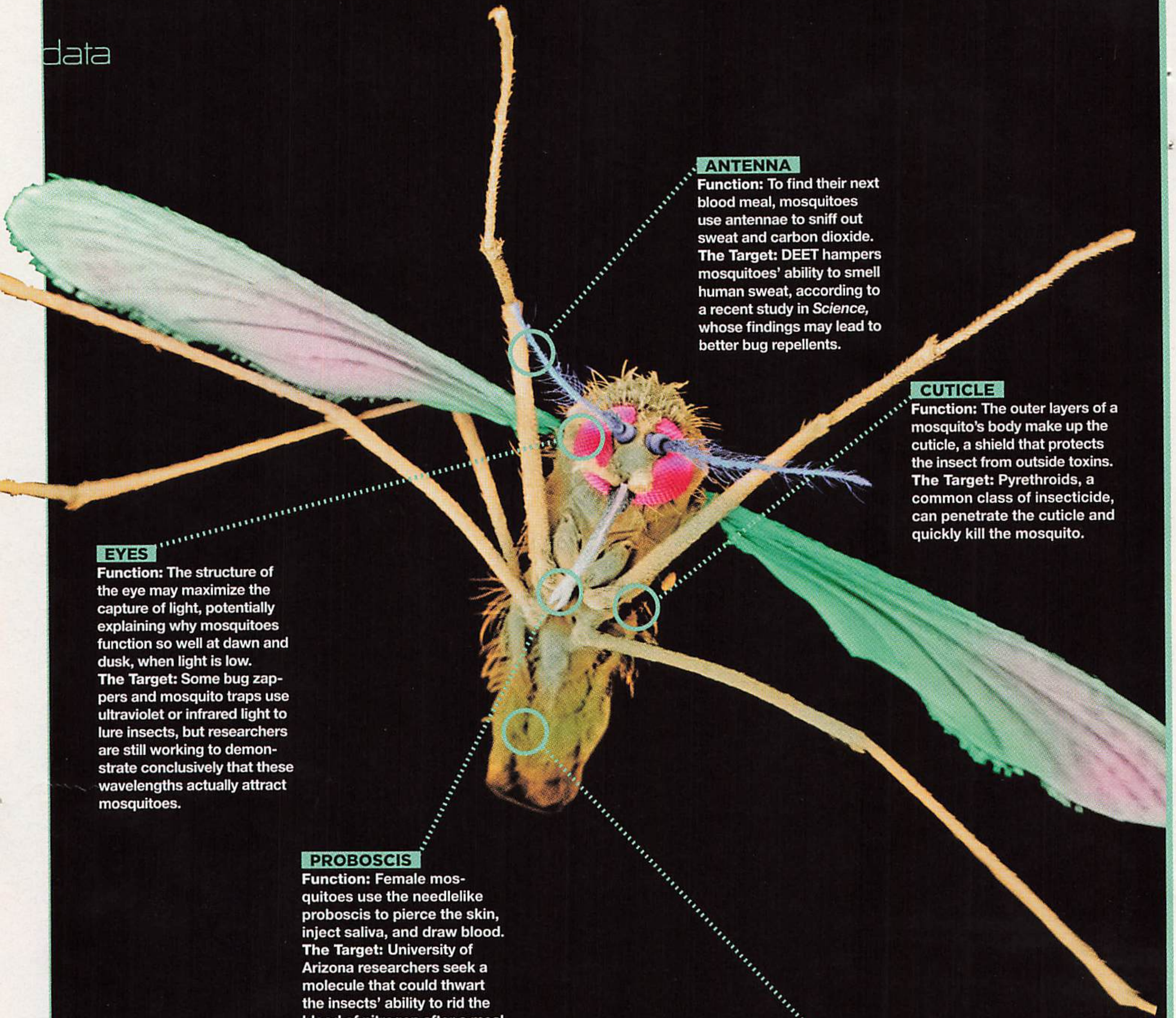
SLICED *MOSQUITO*

The fight against mosquitoes has dragged on for decades, but we just cannot seem to lick these annoying, disease-carrying pests. And things might only get worse—mosquitoes are rapidly growing resistant to a variety of insecticides, and global climate change is allowing them to survive the winter in more places. Such trends have public-health officials worried about the spread of malaria, encephalitis, dengue, and yellow fever. But where there is an insect problem, researchers are close behind. Scientists know more about mosquito physiology than ever, and they are working on manipulating proteins, blocking sense organs, and disrupting metabolism in hopes of ending the mosquito's reign once and for all.

Emily Anthes



ANTENNA
Function: To find their next blood meal, mosquitoes use antennae to sniff out sweat and carbon dioxide.
The Target: DEET hampers mosquitoes' ability to smell human sweat, according to a recent study in *Science*, whose findings may lead to better bug repellents.

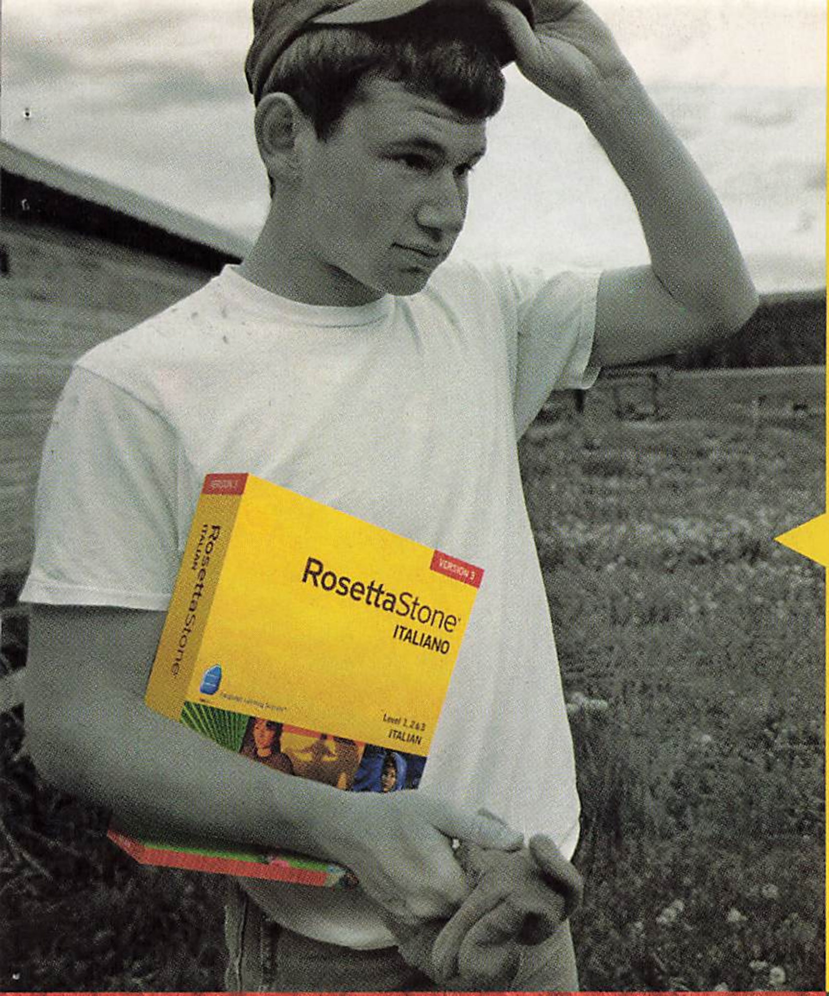
CUTICLE
Function: The outer layers of a mosquito's body make up the cuticle, a shield that protects the insect from outside toxins.
The Target: Pyrethroids, a common class of insecticide, can penetrate the cuticle and quickly kill the mosquito.

EYES
Function: The structure of the eye may maximize the capture of light, potentially explaining why mosquitoes function so well at dawn and dusk, when light is low.
The Target: Some bug zappers and mosquito traps use ultraviolet or infrared light to lure insects, but researchers are still working to demonstrate conclusively that these wavelengths actually attract mosquitoes.

PROBOSCIS
Function: Female mosquitoes use the needlelike proboscis to pierce the skin, inject saliva, and draw blood.
The Target: University of Arizona researchers seek a molecule that could thwart the insects' ability to rid the blood of nitrogen after a meal, not only killing individual females but also preventing them from laying eggs.

ABDOMEN
Function: The abdomen contains many of a mosquito's crucial organs, including the reproductive system.
The Target: After mating, female *Aedes aegypti* mosquitoes have a decreased interest in searching for hosts and taking new mates. Researchers at Cornell University identified 63 proteins in the male mosquito's reproductive glands that may be responsible for the change; these molecules may help to control female mosquitoes—inhibiting their feeding and mating activity.

VOLKER STEGER/PHOTO RESEARCHERS



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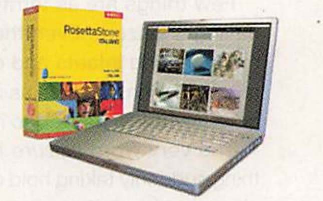

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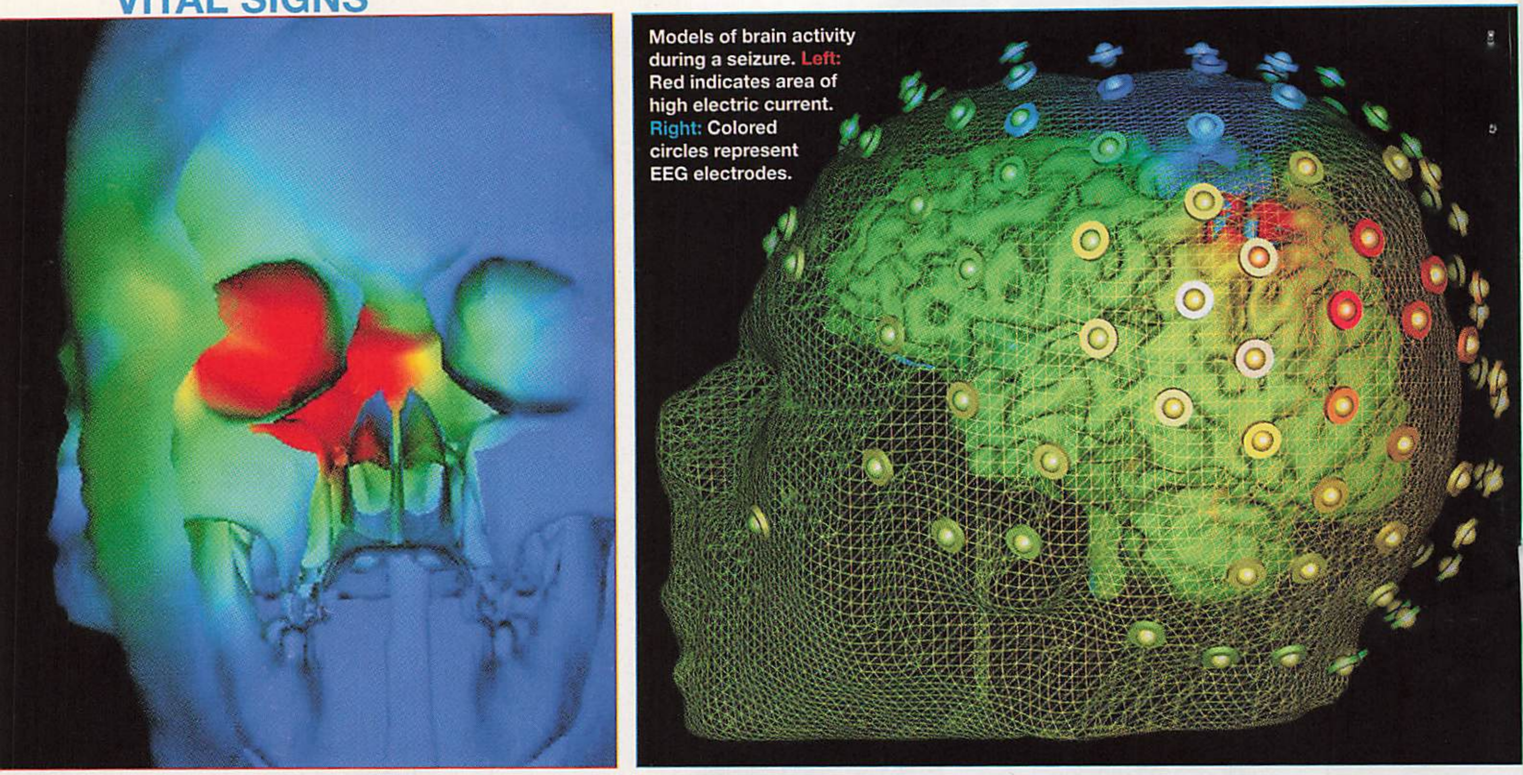

Models of brain activity during a seizure. Left: Red indicates area of high electric current. Right: Colored circles represent EEG electrodes.

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I knew it was a seizure, but what was the cause?

By Mark Cohen

"Help! Doctor! Somebody help me!"

I ran out of my office toward the sound of the woman's panicked voice. She was in the hallway outside one of my examination rooms, holding a 1-year-old child in her arms. The child's body was stiff, her head tilted back, her arms and legs moving rhythmically. Her eyes were open, but she was not looking at her mother or at anyone else. She was having a generalized seizure.

Few things are as terrifying as a child having a seizure. Even though I've seen many seizing infants and children during my more than 25 years as a pediatrician, I have never gotten used to it.

The very word *seizure* hints at something suddenly taking hold of a person and changing his or her nature. The Hmong people of the highlands of Laos describe a seizure as *qaug dab peg*—a phrase that translates as "the spirit catches you and you fall down." (The translation is the title of Anne Fadiman's fascinating 1997 book about cultural differences in medical care.) The expression represents a belief in many cultures that the something taking hold of a person having a seizure is spiritual or divine.

Divine intervention was the furthest thing from my mind as I lifted the child out of her mother's arms and headed for the treatment room. I needed to have her in a safe place, with access to oxygen and other therapies, and then assess what was happening and decide what to do about it. I saw that she was still stiff and unresponsive and that her arms and legs were still making rhythmic movements, but thankfully she was breathing and her lips were pink. I had some time.

A seizure is a symptom of something going on in the brain. Any of us could potentially have one, if our brain happened to be subjected to a strong enough precipitating stimulus, such as trauma, infection, or a sudden drop in blood sugar. With any of these stimuli, the complex and finely coordinated electrical activity of the brain's cortex suddenly degenerates into a storm, a widespread, rhythmic, but purposeless pattern of electrical activity.

Imagine for a moment a huge auditorium filled with people carrying on hundreds of individual quiet conversations. Now imagine that, at the same split second, all those people suddenly begin shouting out a single meaningless sound in unison, over and over again, as if led by some maniacal cheerleader. That's something like what happens in the brain during a seizure.

I reached the treatment room and placed the child on the examining table. One of the nurses attached the leads of a cardiorespiratory monitor, noting that the girl felt quite warm. "Let's check her temperature and oxygen saturation," I said to the nurse, "and bring the oxygen over in case we need it."

"Do you think you're going to admit her?" the nurse asked me.

"Not necessarily," I said. If the child did have a fever and her seizure stopped within 15 minutes, and if her subsequent exam proved normal, this might be just a simple febrile seizure. Common in children between about 6 months and 5 years of age, such seizures carry an excellent prognosis, requiring neither hospitalization nor medication.

"Let's get an IV started just in case, and draw up some Ativan."

If the seizure persisted, I wanted to have medication ready. At this point, however, I would simply watch and wait, hoping that, like most seizures in children, this one would stop fairly quickly.

But I noticed something worrisome: The child's eyes were not staring straight ahead but were deviated to the right. This was a subtle but significant clue, and I filed it in my mind as I continued the assessment.

I turned to the child's mother, who stood, pale and shaky, nearby.

"Has she ever had anything like this before?" I asked her.

"No, never," she answered.

"When did she start getting sick?"

"She started running a fever this morning. That's why I made the appointment."

I saw something worrisome: The child's eyes were staring not straight ahead but to the right.

"Did she have any other symptoms? Vomiting, rash, any sign of pain?"

"No," the mother replied.

The nurse interrupted: "Her temperature is 103.1." That was high, but not excessive for a 1-year-old. Again, young children often run very high fevers with minor viral illnesses. I looked at the child once more. In these situations, continued reevaluation is critical.

To my relief, in just minutes the seizure stopped. The little girl was lying quietly on the table, still pink, still breathing. I checked the oxygen monitor: 97 percent. Good. Now I could relax a bit, but I had to keep probing. What had caused this little girl's seizure? Was it an indication of something that we needed to treat right away? Was she likely to start seizing again very soon? While many conditions can cause a seizure in a child, they fall into only a few common categories. I mulled them over as I began to examine her again, and I ticked off the possibilities.

Highest on the list of causes is infection. Fevers that trigger seizures are most often due to flu, cold, or ear infection, but they can also be due to meningitis. Thanks to modern immunizations, this dreaded infection of the fluid and membranes that surround the brain and spinal cord is nowhere near as common as it once was. I began to make a mental list of tests I would need for this child, and the first one was a lumbar puncture, or spinal tap, to sample her cerebrospinal fluid and rule out meningitis.

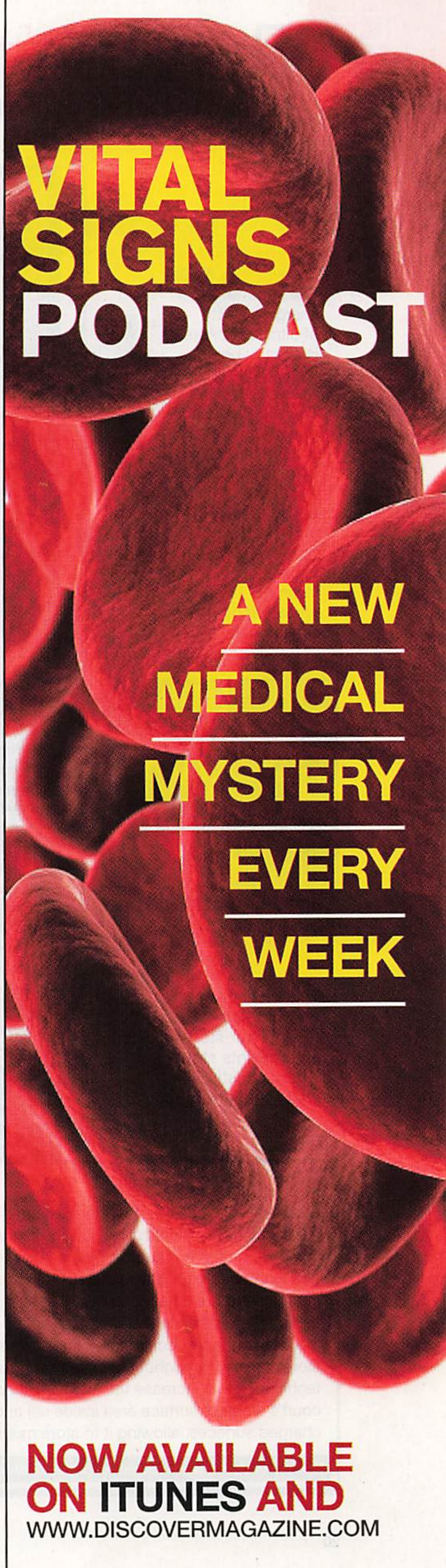
Another possible cause of a seizure is a mass inside the brain, such as a brain tumor. I recalled that the child's eyes had been gazing to one side during her seizure, and now I noticed that, even though the seizure had stopped, she was holding her left arm and leg in an oddly stiff posture. The subtle asymmetry of her eyes and extremities suggested to me that this child's seizure was focal. Focal seizures may be triggered by something going wrong in a specific location in the brain. The problem can sometimes turn out to be, among other things, a tumor. An MRI scan went on the to-do list. I was not going to send this child home tonight.

Some children's brains are simply prone to having seizures. We say that such a child has a seizure disorder, which is also known as epilepsy. We think there is some area of scar tissue or other irregularity in the brain's cortex that acts as an "irritable focus"; it can suddenly trigger a seizure, frequently with no provocation at all. This irritable focus often shows up on an electroencephalogram (EEG), a recording of the brain's spontaneous electrical activity. Fortunately, some medications can decrease the frequency of seizures in people with epilepsy. The drugs have some side effects, but most patients can live healthy and active lives. However, the focal nature of the seizure I had just witnessed had me very worried that this little girl might have something worse inside her brain.

I telephoned a pediatric colleague and arranged for the child to be transported to the hospital. I checked the reports in the computer as they came in over the next couple of days. I was pleasantly surprised to find that her spinal fluid was normal, her MRI did not show a tumor or any other abnormality, and her EEG showed perfectly normal brain activity with no sign of a seizure focus. The pediatric neurologist decided that she did not have epilepsy and did not need to be treated with anticonvulsant medication.

She is home now, and doing wonderfully. With any luck she'll never have another episode like this one. So why did she have a seizure? We can't explain it, other than to chalk it up to the mystery of a child's brain. In this case, I was delighted to have been wrong. ■

Mark Cohen is a pediatrician with Kaiser Permanente in Santa Clara, California. The cases described in Vital Signs are real, but names and other details have been changed.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ULTRACAPACITORS COULD BE THE MISSING LINK IN THE EVOLUTION OF THE ELECTRIC CAR.

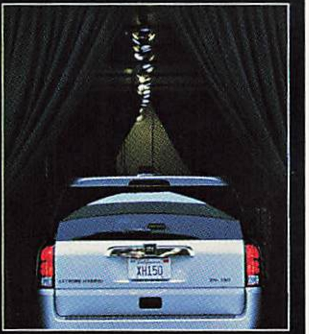
BY STEPHEN CASS

Extreme Hybrid SUV by AFS Trinity. Fast Energy Storage. 150MPG.

They're not quite as sexy as the "flux capacitor" that powered the time-traveling DeLorean roadster of the *Back to the Future* movies. But ultracapacitors look set to have a bright future with hybrid and electric cars.

Capacitors have the handy ability to store and release electrical energy very quickly—much more quickly than the batteries and fuel cells already being used in electric and hybrid-electric cars. Unfortunately, typical capacitors have been able to store only tiny amounts of charge, making them useless for driving the power-hungry engines these cars use. Not so ultracapacitors. While they still can't store as much total energy as a fuel cell or a battery, ultracapacitors—also known as electrochemical capacitors—can supply the burst of energy needed to accelerate up a hill or around another car on the highway. They can also soak up energy that would otherwise be lost during braking, storing it for later use.

The focus of intense research by automobile makers in recent years, ultracapacitors are finally being tested on the road. AFS Trinity Power in Bellevue, Washington, recently displayed a modified hybrid SUV (pictured above and at right) that uses ultracapacitors alongside batteries and an internal combustion engine, and major manufacturers such as Honda and Toyota have also been experimenting with the technology.



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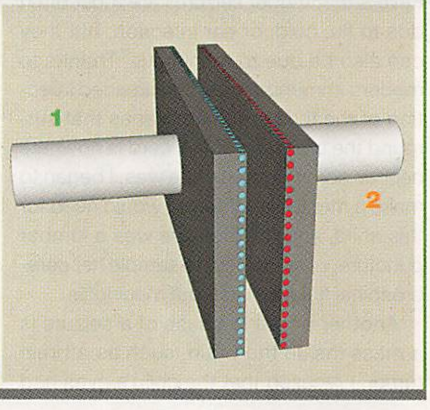
how it works

A capacitor is a device that stores electric charge. Whereas a battery or a fuel cell creates electricity using chemical reactions, the most basic type of capacitor employs two narrowly separated conductive plates. After a power source charges the capacitor via electrodes connected to these plates (1 and 2), one plate has an excess of positive electric charges and the other an excess of negative charges (red and blue dots, respectively); the charge difference stores energy within the capacitor. Since charges build up only on the plate surfaces, capacitors can't store as much energy per pound as a battery, which stores energy throughout its entire bulk. An ultracapacitor gets around this by using techniques that increase the effective surface area (similar to how our lungs tuck a tennis court's worth of surface area inside us) and decrease the effective separation between charged surfaces, allowing it to store much more energy than a basic capacitor.



For more, visit www.nrel.gov/vehiclesandfuels/energystorage/ultracapacitors.html.

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Pulstar™ pulse plugs improve the performance and mileage of your car, truck or SUV* —**100% guaranteed***

It's a pulse plug, and here's why its patented technology should be in your engine

Sure, you've heard the claims before: enjoy more power, better drivability, or increased fuel mileage after adding something simple to your engine. Well, this time the claims are true—except for the "something simple" part. A pulse plug is *not* a simple, old-fashioned spark plug. In fact, the eight patents that its technology is based on come from plasma research at the world famous **Sandia National Laboratories**—and yes, that *is* rocket science.

How it works: Electrical energy from the engine's coil is stored in the pulse plug's built-in capacitors. At the exact moment needed, that energy is re-released in an amazingly quick, powerful, high-energy pulse.

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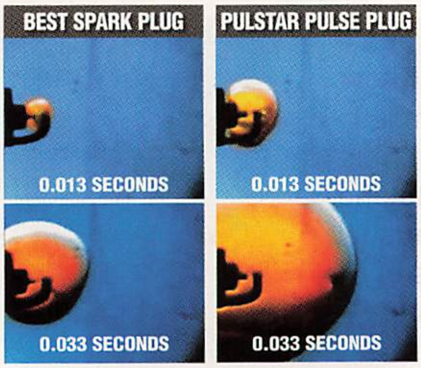
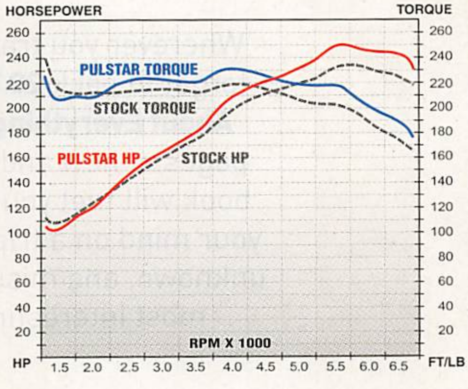


This comparison test was captured on high-speed video (68,000 frames/sec.) by a respected independent laboratory.† It shows the pulse plug's flame kernel growing larger and faster. Fuel burns sooner and more efficiently, which results in added power and/or better fuel mileage.



This stock Nissan 350Z was independently dyno tested by ***Modified Magazine.***

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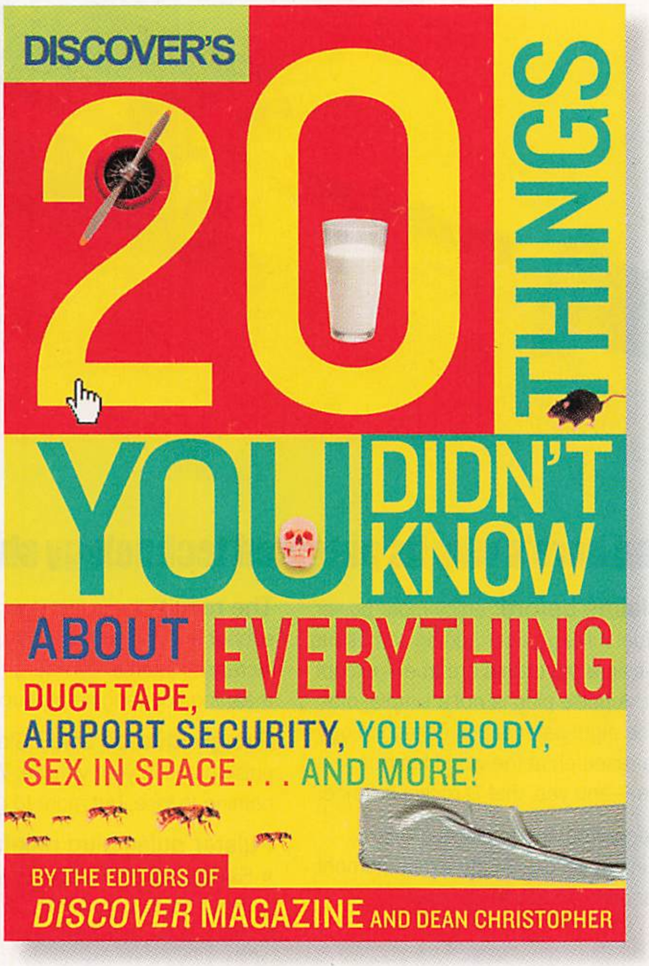
Bees fly on every continent except Antarctica.

The Canary Islands boast the world's "best climate," with some 300 totally sunny days a year.

A Hindu temple in Deshoke, India, houses more than 20,000 rats.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BY THE EDITORS OF
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At 26 feet high, the mosquito statue in Clute, Texas, is the world's largest.

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Avon, Ohio, is the duct tape capital of the world.

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A SEA CHANGE

North to south, east to west, the earth is soaked with water: the frigid spray of the Arctic Ocean; the turbulent Atlantic; the little-studied Southern Ocean (first delimited in the year 2000), which hugs the continent of Antarctica; the balmy Indian Ocean; the paradisial Pacific. These massive bodies occupy more than 70 percent of our planet's surface. Around the world the sounds of breaking waves soothe us; the tumult of the surf inspires us, the contents of the seas sustain us. But for how long? While environmentalists scramble to right our wrongful practices on land, marine biologists declare that our abuses have changed the very chemistry of the waters of life. The imperiled include all things shelled, finned, webbed, and wondrous, from minute plankton to the mighty blue whale. It is not just important that you read what follows; it is essential. We and the sea are one.

The Editors

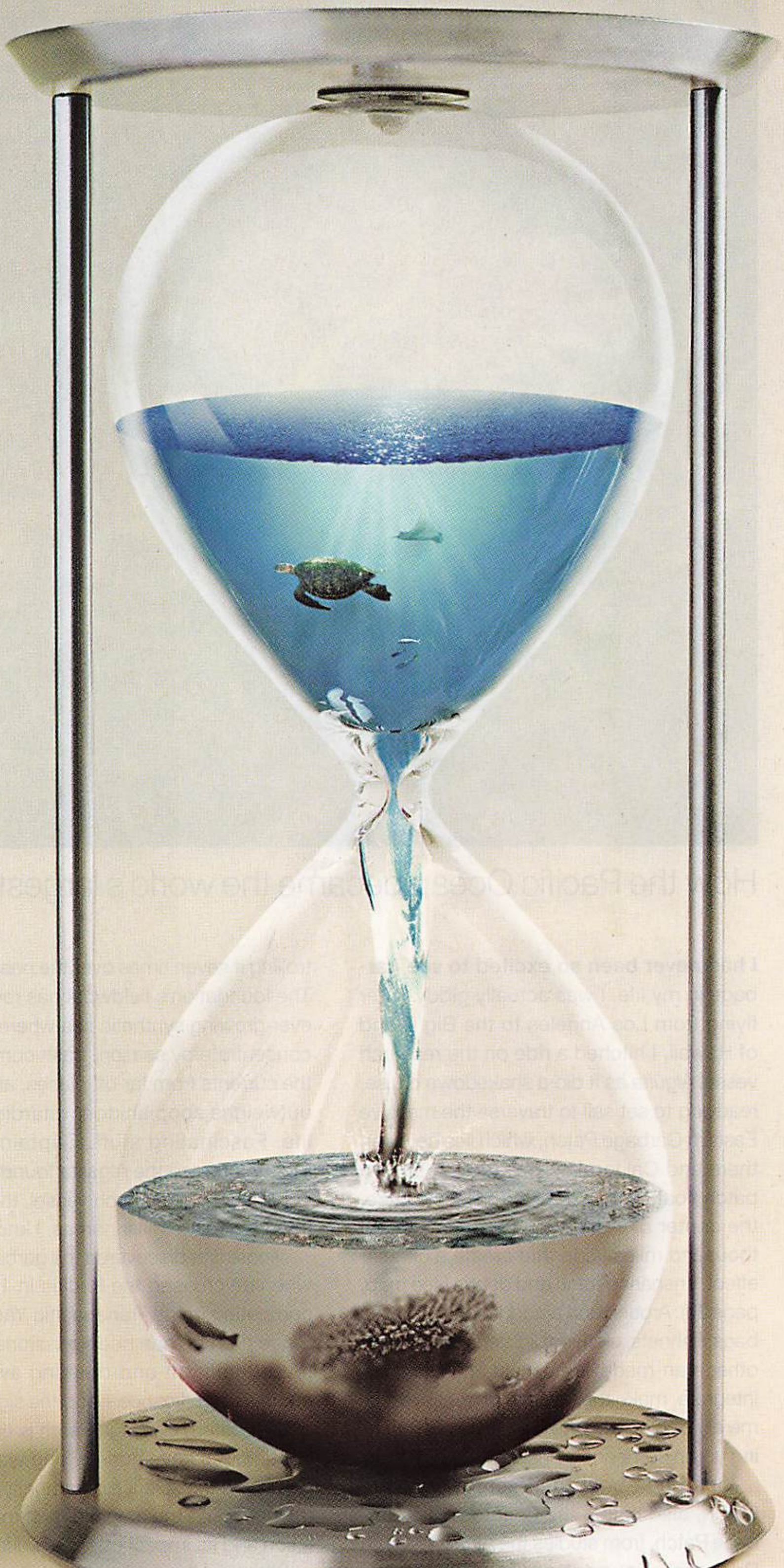


ILLUSTRATION BY C. J. BURTON

JOEL PASCHAL/ALGALITA MARINE RESEARCH FOUNDATION

How the Pacific Ocean became the world's largest dump.

By Thomas M. Kostigen

I had never been so excited to see garbage in my life. I was actually giddy. After flying from Los Angeles to the Big Island of Hawaii, I hitched a ride on the research vessel *Alguita* as it did a shakedown cruise, readying to set sail to traverse the massive Eastern Garbage Patch, which lies between there and California. This rubbish-strewn patch floats within the North Pacific Gyre, the center of a series of currents several thousand miles wide that create a circular effect, ensnaring trash and debris (see map, page 26). Around and around: bottles, plastic bags, fishnets, clothing, lighters, and myriad other man-made items, held until they disintegrate, make their way to distant seas, or merely bob among the waves before washing up on someone's beach.

I learned about the Eastern Garbage Patch, also called the Great Pacific Garbage Patch, from studies the Algalita Marine Research Foundation, based in Long Beach, California, has conducted while trolling it seven times over the past decade. The foundation's fieldwork has revealed an ever-growing synthetic sea where particles concentrate by season, trash commutes in the currents from far-off places, and plastic outweighs zooplankton, retarding ocean life. Fascinating stuff. Captain Charles Moore founded the Algalita foundation and commands its research vessel, the *Alguita*. (Maddeningly similar names, I know.)

Moore first discovered the garbage patch when he crossed the Pacific in 1997 after competing in the Transpacific Yacht Race. Since then he has been passionate about investigating it and creating awareness about its significance—and the significance of the Eastern Garbage Patch is enormous. His findings have gone a long way toward educating the science community, if not yet the public, on the magnitude of marine pollution and its impact on life—all life.

Sitting on the deck of his boat in Hilo Harbor, Hawaii, last January, he tells me about the crew's next mission, which is just days away: to map the size, content, and density of the Eastern Garbage Patch. The patch, you see, isn't well understood. People think it's like a solid mass of trash you'd find at a dump site (I've been asked: "Can you walk on it?" "Can you land a plane on it?"), but it's really diffuse, like "plastic soup," as Moore describes it.

But don't for a second think that its mass isn't substantial. Its sprawl may cover an area as much as one and a half times the size of the United States, Moore says, and to a depth of 100 feet, if not deeper. But because this rubbish is in the ocean, it drifts. Fragments peel off here and there; some of it drops to the ocean floor. Even for those who do understand the makeup of the garbage patch, its effect on the marine ecosystem is as yet largely unknown.

Moore, 61, is a scruffy sea captain whose blue eyes are both sad and keen. His salt-and-pepper hair is typically covered by an

Opposite: Captain Charles Moore attaches a tracking buoy to a floating mass of garbage. Right: Moore aboard the research vessel *Alguita* with ocean trash collected on his latest mission. Below: A turtle caught in a discarded fishnet.

odd-fitting hat ("Die Trying" emblazoned across its brow). He is, as most sailors go, an old salt.

"In the central North Pacific Gyre, pieces of plastic outweigh surface zooplankton by a factor of 6 to 1," according to a report based on Moore's research. "Ninety percent of Laysan albatross chick carcasses and regurgitated stomach contents contain plastics. Fish and seabirds mistake plastic for food. Plastic debris releases chemical additives and plasticizers into the ocean. Plastic also adsorbs hydrophobic pollutants like PCBs and pesticides like DDT. These pollutants bioaccumulate in the tissues of marine organisms, biomagnify up the food chain, and find their way into the foods we eat."

You'll notice the emphasis on plastics. Most other materials biodegrade or are not as buoyant as plastics, which do not biodegrade. Their resilience is also their menace, as today plastics have invaded the most distant places, from the Bering Sea to the South Pole. Indeed, when I was exploring a remote beach past the South Point of Hawaii, I found pill bottles from India and mashed pieces of various products—oil containers, detergent jugs, plastic caps—with Russian, Korean, and Chinese writing on them. It's hard to get your brain around these connections. But float these things did, to shore.

How trash makes its way to the garbage patch is pretty straightforward. When a plastic cup gets blown off the beach in, say, San Francisco, it gets caught in the California Current, which makes its way down the coast toward Central America. Somewhere off the coast of Mexico it most likely meets the North Equatorial Current, which flows toward Asia. Off the coast of Japan, the Kuroshio Current might swoop it up and yank it eastward again, until the North Pacific Current takes over and carries it past Hawaii to the garbage patch. These are the currents that make up the North Pacific Gyre. Moore says it takes a year for material to reach the Eastern Garbage Patch from Asia and several years for it to get there from the United States. Now multiply that one cup by billions of plastic items over years and years—actually about 60 years, starting after World War II, when we really began to make plastic products en masse.

Marcus Eriksen, Algalita's director of research and education, has studied that connection between the increasing amount of plastic found in the ocean and the increasing amount of plastic produced: In 1999 there was 0.002 gram of plastic per square meter of ocean in the Eastern Garbage Patch, and as of 2005 there was 0.004 gram per square meter in the same place. In that same period plastic production in North America alone experienced double-digit growth, topping 113 billion pounds in 2006, according to the plastics division of the American Chemistry Council in Arlington, Virginia.

Beyond plastic degradation and its toxic ramifications, other refuse issues ensue. Twenty-mile castaway fishnets snare sea turtles, dolphins, and other animals, endangering their populations; birds mistake trash for food, eat it, and die; jellyfish get sick; gnarly junk washes back to shore—some of it hazardous waste. The Eastern Garbage Patch isn't just a problem for those living in the middle of the ocean; it's a problem for those of us who are landbound as well.

Moore likens the patch to a cemetery and the trash heading toward it to a series of funeral processions. "There are bigger particles in the processions because they haven't degraded as much yet," he says. But inside the patch, where trash has been disintegrating for years—even decades—the particles are much finer. The United Nations Environment Programme (UNEP) reports that 70 percent of marine litter sinks. So who knows what is also building up on the ocean floor?

To be sure, the Eastern Garbage Patch isn't a lone phenomenon. Off the coast of Japan there is a Western Garbage Patch. And each of the other oceans has its own, albeit smaller, floating patches of debris. Even so, the Eastern Garbage Patch—rooted square between California and Hawaii—is most intriguing and draws the greatest attention because of its size and the fact that it lies closest to the biggest trashmonger on the planet, the United States.

The *Alguita*'s journey last winter was closely followed by the many who had become aware of the floating garbage dump. Crew members kept a ship-to-shore blog, writing: "We know this plastic trash is a problem.... But in order to get the world to pay attention and start making changes, we need to *prove* it. We need accurate data and real hard numbers, so we can bring this information to governments, industries, and the public and show them just how serious this issue has become."

Blog responses came from all over the world, from grade-school children to the elderly, scientists to laypeople.

One asked, "Do we have an answer to the question 'Yeah, it's gross, but why should I put it high on my list of world problems that need our immediate attention?'" It is a good question because marine pollution is one of the most underreported stories today. One glaring answer to the question is this: Around

TOP: ALGALITA MARINE RESEARCH FOUNDATION. BOTTOM: GREENPEACE/CARE, MARCO/SPLASHDOWNDIRECT

2.5 billion people rely upon fish for at least 20 percent of their animal protein. When fisheries get polluted, so does the food we eat. (See "Ocean Reflux," page 28.)

The UNEP reports that today 80 percent of all marine debris that washes ashore—such as trash and toxic matter—originally comes from shore-based activities that could have begun with innocent fun, such as picnics and beach outings and the like. Farther inland, rivers and streams carry trash to the sea. Marah Hardt, a research fellow at the Blue Ocean Institute on Long Island in New York, says most people have no clue about their effect on ocean life because they can't see it. "The ocean is way out there, they think," she says. Meanwhile, their garbage disposals, drainpipes, and sewers can lead directly to it. Factories dump. Air pollution seeps. This is how the oceans become contaminated.

Solutions offered by the public range from thoughtful to wacky: "Why couldn't it be possible to collect the larger pieces of trash by skimming the most polluted concentrations with troll nets and attaching them to helicopters that would then deposit them into the path of the ongoing lava flow of Kilauea to be consumed and incorporated into new rock?" one person asked in a blog comment. Other ideas include vacuuming the sea and converting the plastic into an alternative energy source (plastics are made from petroleum).

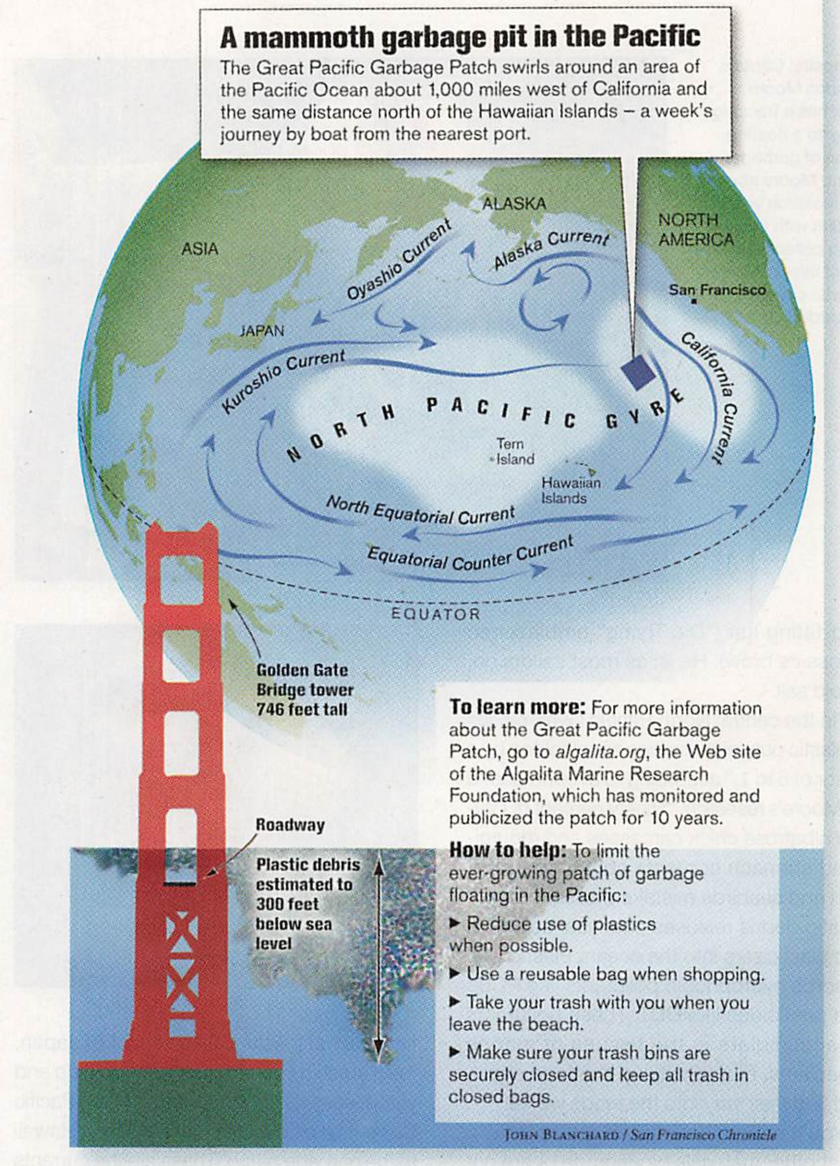
"We get about one suggestion a week," says Anna Cummins, an *Alguita* crew member and education adviser at Algalita.

Moore says the only solution is to prevent more debris from entering the ocean; it is futile to try to clean out whatever exists there now. And without changing our habits, the garbage patch will only continue to grow.

Alexandra Cousteau, a National Geographic Emerging Explorer and the granddaughter of the famous explorer Jacques Cousteau, believes awareness and education are the keys to ocean preservation. She and her brother, Philippe, use the media and speak about their environmental experiences to educate people about the importance of protecting the oceans and freshwater resources. Cousteau reminds me that we are all indelibly linked to the oceans. "We live on a water planet," she says. "Water is life." Pollution, therefore, is unacceptable, and the Eastern Garbage Patch, anathema.

A mammoth garbage pit in the Pacific

The Great Pacific Garbage Patch swirls around an area of the Pacific Ocean about 1,000 miles west of California and the same distance north of the Hawaiian Islands – a week's journey by boat from the nearest port.



To learn more: For more information about the Great Pacific Garbage Patch, go to *algalita.org*, the Web site of the Algalita Marine Research Foundation, which has monitored and publicized the patch for 10 years.

How to help: To limit the ever-growing patch of garbage floating in the Pacific:

- ▸ Reduce use of plastics when possible.
- ▸ Use a reusable bag when shopping.
- ▸ Take your trash with you when you leave the beach.
- ▸ Make sure your trash bins are securely closed and keep all trash in closed bags.

JOHN BLANCHARD / *San Francisco Chronicle*

The samples of trash and marine life gathered during *Alguita*'s winter voyage—buckets of plastic, garbage, and algaelike organisms—are still being evaluated and lab tested, and the results will be available this summer. But Moore tells me the major finding, in his mind, was the discovery of the further accumulation of trash outside the garbage patch itself, near the international date line—a higher-density collection of waste making its way to the patch. "You can now make a new hypothesis that *all* food in the ocean contains plastic," he says. The evaluation of particle ratios—the measure of plastic to organic matter—inside and outside of the patch may bear that out. So may analysis of seawater for the chemical signature plastic leaves behind.

Meanwhile, Moore has plans to go farther and test new waters sometime this fall or early next year. If he can prove that the travesty of plastic pervasiveness in the ocean is worsening (by tracking the amount of plastic per square mile of ocean, as this last voyage did) and that it has an impact on more of the various types of ocean life, even perhaps on the carbon sequestration process that the oceans offer, then international policy might finally begin to address the issue of trash in our seas. That, anyway, is the hope of all his fieldwork.

I remember sailing miles offshore with Captain Moore and his crew in the days before their trek, taking in the sight of two whales spouting and playing, wondering just how much plastic they had ingested.

It made me think how tragic it is that now when we say "blue ocean," we may be talking about it not so much in the sense of its color but in the sense that it is sad. And for that we have to take more responsibility.

Visit the Better Planet blog at **blogs.discovermagazine.com/betterplanet.** ■

JOHN BLANCHARD/SAN FRANCISCO CHRONICLE

NASA, ESA, T. Megeath (University of Toledo) and M. Robberto (STScI).

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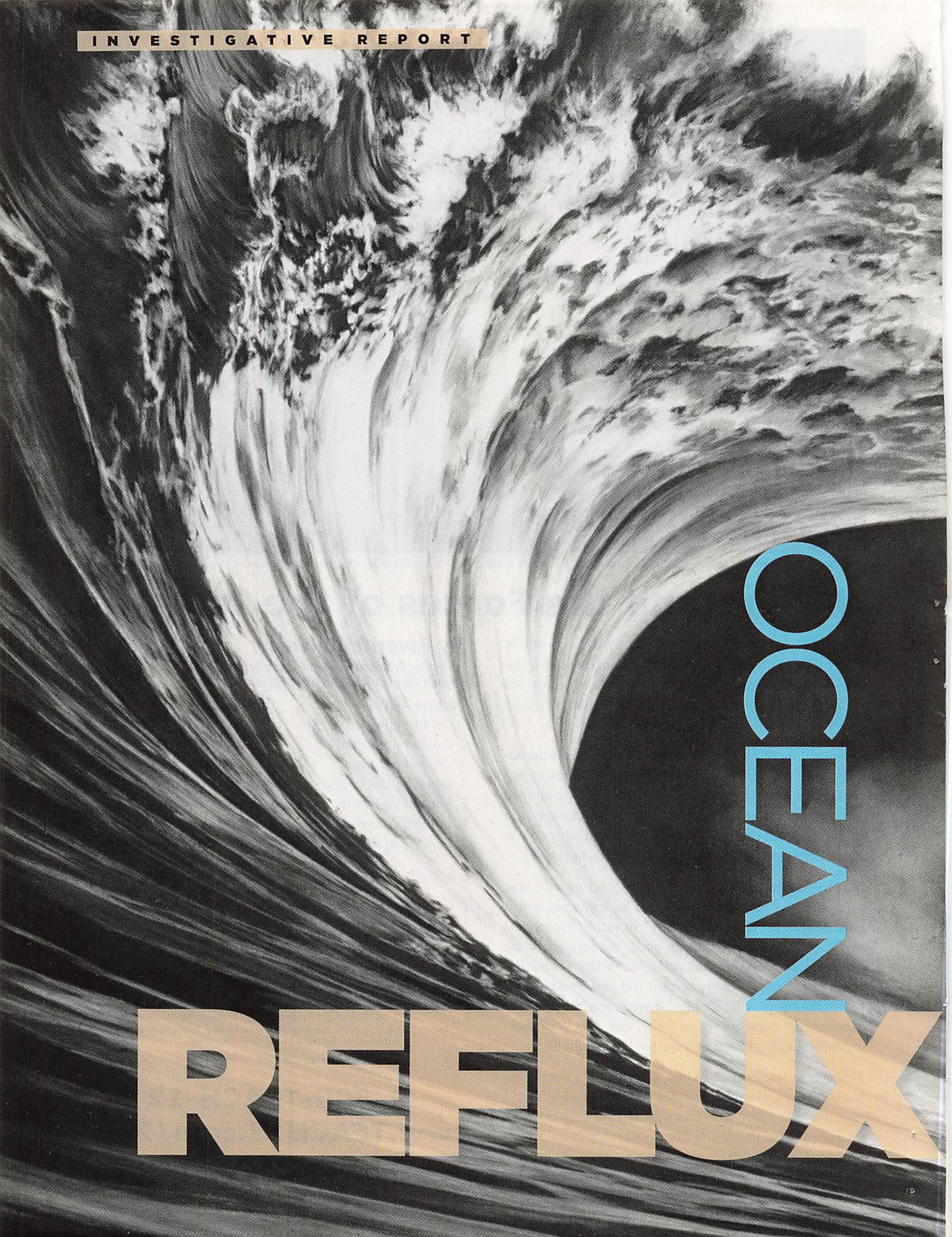
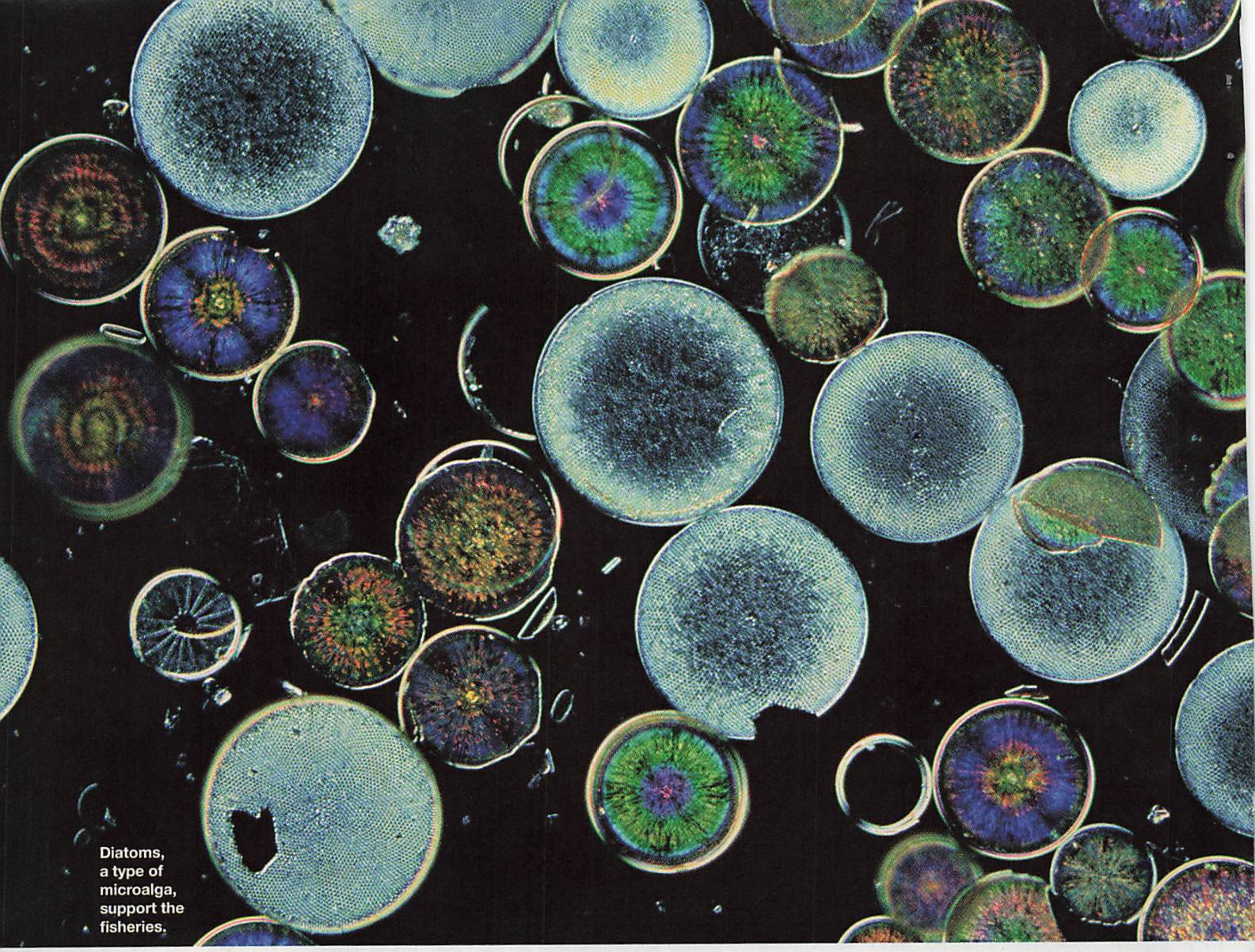


OCEAN REFLUX

By soaking up carbon dioxide from industrial emissions, the oceans are becoming more acidic, threatening the foundation of life in the sea.

BY **KATHLEEN McAULIFFE** ARTWORK BY **ROBERT LONGO**



Diatoms, a type of microalga, support the fisheries.

It all seemed so convenient: As our smokestacks and automobile tailpipes spewed ever more carbon dioxide into the air, the oceans absorbed the excess. Like a vast global vacuum cleaner, the world's seas sucked CO_2 right out of the atmosphere, mitigating the dire consequences of global warming and forestalling the melting of glaciers, the submergence of coastlines, and extremes of weather from floods to droughts. So confident were we in the seas' seemingly limitless capacity to absorb our gaseous waste that, by the turn of the millennium, the United States, Germany, and Japan were actually proposing to compress CO_2 from power plants into a gooey liquid and pipe it directly into the abyss.

The first tests of the plan were an eye-opener. When the compressed material was introduced into laboratory tanks, the spines of sea urchins and the shells of mollusks dissolved. Surprised, researchers launched studies to see how marine animals in laboratory tanks and in the wild would fare with CO_2 concentrations much lower than those in the original tests. They were stunned. "We found that mere absorption of CO_2 from the atmosphere into the ocean was enough to harm marine creatures," says Ken Caldeira, a chemical oceanographer now at the Carnegie Institution of Washington in Stanford, California.

The problem was that, having swallowed hundreds of billions of tons of greenhouse gases since the start of the Industrial Revolution, the oceans were becoming more acidic. And not just in a few spots. Now the chemistry of the entire ocean was shifting, imperiling coral reefs, marine creatures at the bottom of the food chain, and ultimately the planet's fisheries.

In 2003 Caldeira reported these findings in the journal *Nature,* coining the term "ocean acidification." One might think the news would spread around the world with the speed and force of a tsunami. But scientific discoveries take time to be digested and disseminated. Only recently have the far-flung implications of this development begun to register beyond the rarefied sphere of marine biologists.

"It's the most profound environmental change I've seen in my entire career, and nobody saw it coming," says Thomas E. Lovejoy, a biologist and president of the H. J. Heinz III Center for Science, Economics and the Environment in Washington, D.C.

Lovejoy is not the only one alarmed by the development. "It's just been an absolute time bomb that's gone off both in the scientific community and, ultimately, in our public policymaking," Rep. Jay Inslee (D-Wash.) told *The Washington Post* when first briefed on the matter in the spring of 2006. Congress is now scrambling to get up to speed by holding hearings on the issue and discussing federal legislation that could allocate roughly $100 million to study the

PREVIOUS PAGES: UNTITLED (GÖTTERDÄMMERUNG), 2005/COURTESY THE ARTIST AND METRO PICTURES. THESE PAGES: DR. DARLYNE A. MURAWSKI/GETTY IMAGES

impact of industrial emissions on marine ecosystems.

Even the fishing industry has been caught off guard. Fisheries are "the ultimate canary in the coal mine of ocean acidification," says Brad Warren, the former editor and publisher of *Pacific Fishing* magazine, who recently launched the nonprofit Sustainable Fisheries Partnership to encourage seafood enterprises to confront the problem through policy initiatives.

While the existence of global warming was fiercely debated for decades, ocean acidification has been rapidly accepted by the scientific community as a real and imminent hazard. "It is very complicated to pin the heating of the planet on a single gas, but ocean acidification involves straightforward chemistry," says Robert B. Dunbar, professor of geological and environmental sciences at Stanford University. Since it is easy to chart the step-by-step progression of the problem, there is widespread consensus that we are marching toward disaster at a pace that is impossible to ignore.

An analysis of CO_2 preserved in ice cores shows that for more than 600,000 years the ocean had a pH of approximately 8.2 (pH is the acidity of a solution measured on a 14-point scale, with a pH below 7 being acidic and above 7, basic). But since 1800, the beginning of the Industrial Revolution, the pH of the ocean has dropped by 0.1 unit. That may not sound like much, but pH is a logarithmic scale, so the decline in fact represents a whopping 30 percent increase in acidity. With the oceans now absorbing manmade CO_2 at a rate of 22 million tons a day and climbing, the situation is certain to worsen rapidly. More than a dozen projections by the International Panel on Climate Change indicate that ocean pH by the end of the century could drop as low as 7.8, which would correspond to a 150 percent increase in acidity since preindustrial times. "A drop of that magnitude is more than we've seen in 20 million years," says Richard A. Feely, supervisory oceanographer at the National Oceanic and Atmospheric Administration (NOAA) Pacific Marine Environmental Laboratory in Seattle. "That's going to profoundly change the ecology of the sea as we now know it, in ways that could potentially be devastating."

OSTEOPOROSIS UNDER THE SEA

Most vulnerable to the assault of higher acidity, scientists say, is any creature that makes a calcium carbonate shell. A look at the chemistry of ocean acidification explains why. When CO_2 from the atmosphere combines with water, it produces carbonic acid (the ingredient that gives soft drinks their fizz) and decreases carbonate ions, a key building block of marine animals' shells. As the oceans become more acidic, this material will become increasingly scarce, hindering the ability of shelled organisms to make and maintain their homes. Like human bones whittled by osteoporosis, their exoskeletons will grow thin and brittle or—mirroring what happened to the test animals at CO_2 injection sites—dissolve.

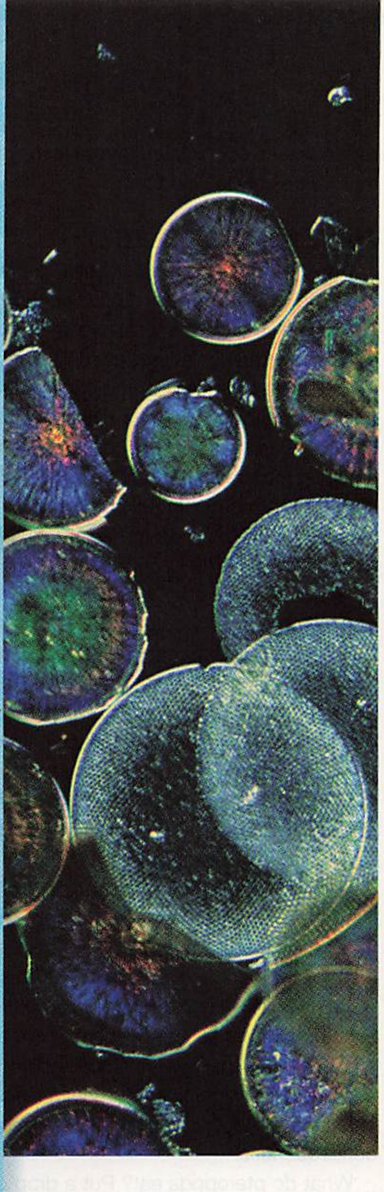
The range of creatures in imminent danger from this hazard includes mollusks and crustaceans such as clams, oysters, lobsters, and crabs; large sea creatures for which shellfish is a dietary staple, notably seals, otters, and walruses; and most worrisome of all, plankton and other microscopic organisms that sustain mighty whales and fish big and small.

To make matters worse, German and Japanese researchers recently increased CO_2 levels in seawater and found that the greenhouse gas can damage some marine organisms directly: Squid slowly asphyxiated as the excess CO_2 crowded out oxygen in their blood, and fish embryos and larvae were abnormally small and less likely to survive.

DISSOLVING THE CORAL REEFS

Also endangered by rising acidity are coral reefs, home to an astonishingly diverse range of aquatic life. Though reef resembles rock, it is actually made up of a teeming city of anemone-like creatures known as polyps. These tiny organisms wave their tentacles in the currents to snatch tidbits of food, all the while secreting shells to anchor their trunks. After the animals die, layer upon layer of their skeletons create the exotic structures we call coral reefs, but according to scientists, they will begin to crumble as corrosive waters undo the work of countless generations of polyps.

"Today's reefs are as much as 5,000 years old, and they will start to fall apart within a decade or so if we don't radically change how we do business," contends Christopher Langdon, a biological



After the FALL

Species evolve alongside each other in intricate relationships, so when one group is disrupted, another may flourish. Should ocean acidification proceed unfettered, we will be left with winners, losers, and a pile of rubble and slime.

THE LOSERS

- **Coral:** the species. Unable to cope with the decrease in available calcium carbonate, these creatures will start to die.
- **Coral reefs:** the ecosystems. The demise of coral spells trouble for a million other species that feed near, live in, or derive protection from the reef environment: microalgae, also known as diatoms, sea urchins and other echinoderms, grazing fish, and foraminifera.
- **Shelled sea creatures.** Anything with a calcium carbonate shell, from microscopic plankton to clams and oysters to pteropods.

THE WINNERS

- **Cyanobacteria.** These nitrogen-fixing, photosynthetic bacteria, also known as blue-green algae, are found in numerous habitats—in soil and lakes as well as the oceans. Unlike calcifying ocean species, they will very likely benefit from an increase in marine CO_2, which provides them with more raw material for manufacturing chemical energy.
- **Dinoflagellates.** Like cyanobacteria, these generally single-celled organisms draw energy through photosynthesis, with many living as symbionts inside coral. Temperature-stressed corals will discharge their dinoflagellate partners, resulting in coral "bleaching," but the organisms can also live independently and may do so more easily in an ocean where CO_2 is becoming more readily available.
- **Seaweed.** Otherwise known as macroalgae, seaweed competes with coral for light and space. Since most seaweed grows much more rapidly than coral, once the balance is tipped, any chance of coral recovery is all but completely choked off.

Carl Brenner

oceanographer at the University of Miami's Rosenstiel School of Marine and Atmospheric Science.

The first hint that this might happen emerged more than a decade ago, when Langdon, working in Biosphere 2, grew corals in a swimming pool–size tank. The corals thrived when calcium carbonate was added to the water but did poorly without it. Ocean acidification wasn't a recognized threat at the time, so Langdon's findings just sat there. But today, pulled up from the void, they are sounding alarms. Working from his Biosphere data, Langdon calculates that the rise in CO_2 pollution since 1850 is stunting the growth of today's tropical corals by 10 to 15 percent.

Meanwhile, warming seas, human poaching, agricultural runoff, and other forms of pollution have also been taking a toll on coral, as documented by just-published measurements of Australia's Great Barrier Reef between 1988 and 2003. In that time frame—a mere 15 years—the world's oldest and largest reef showed an alarming 21 percent decline in growth. This steep downward trend is far greater than even Langdon expected and makes him wonder whether ocean acidification may be acting synergistically with the other destructive forces to greatly compound the damage.

With so many environmental stresses clouding the future of our fragile reefs, the emergence of yet another threat has marine biologists badly shaken. "When I first realized that ocean acidification was happening and the scale of the problem, I was sick about it," admits Joan Kleypas, a coral expert at the National Center for Atmospheric Research (NCAR) in Boulder, Colorado. The insidious, creeping nature of the threat has her particularly concerned. "Bleaching, caused when rising temperatures lead corals to expel the algae that give them their color, often kills corals outright," she says. "It's shocking. But ocean acidification is an invisible, chronic stress that's hard for people to believe. It's like hypertension in a person, slowly getting worse and worse without any visible symptoms."

Lest there be any doubt about the fate that awaits coral in a corrosive world, a recent paper published in the journal *Science* provides a stark warning. The authors of the report, marine biologists Maoz Fine and Dan Tchernov, raised coral specimens in tanks of water with a pH of 7.3, roughly as acidic as the oceans are expected to become sometime in the next century. In response, the hard coral did a vanishing act, and the polyps that once resided in it reverted to a naked existence. "If seeing is believing," Kleypas observes, "that picture says it all."

Should the reefs vanish, the vast populations of aquatic life they support will not be the only casualties. Islands that are atolls, with foundations of coral sediment, could crumble into more acidic seas, experts say. Reefs also form a barrier between land and ocean, preventing beach erosion and creating sheltered sanctuaries for mangroves, birds, and other wildlife. And coral may have still other important functions, as yet unrecognized.

Just two decades ago, scientists discovered that colorful tropical reefs have ghostly counterparts in deep, cold waters throughout the world's oceans. White as bone, they live as much as three miles down where no light penetrates, feeding off dead marine matter that sinks from above. These corals grow in dense thickets, some of them 30 feet tall, off the coasts of Scotland, Norway, Alaska's Aleutian Islands, and many other places. Indeed, cold-water reefs turn out to be 10 times as abundant as their much better-known tropical cousins. Yet for all their prevalence, these cold-water varieties have barely been explored because of their inaccessibility. Should corrosive waters soon claim them, we may realize their value only in hindsight.

PERIL AT THE POLES

Coral may be the poster child in the effort to rouse public concern about ocean acidification, yet many scientists worry even more about how the sea's smallest and least familiar denizens will adapt to the change. Biological oceanographer Victoria Fabry of California State University at San Marcos has spent years studying pteropods, thumbnail-size creatures that flutter through frigid polar and subpolar waters using flaplike wings. When startled they retract into shells that are normally smooth and translucent. But Fabry found that in water as corrosive as their aquatic habitat may be in 2100, the shell of at least one pteropod species turns opaque and begins to dissolve. To Fabry this suggests that pteropods may become vulnerable to predation in a more acidic world and dwindle in number or, in some regions, even die out. Indeed, she says, they may already be suffering adverse consequences, a possibility she is currently investigating.

"Pteropods in Peril" is not the stuff of headlines, nor have Fabry's findings grabbed our attention like the plight of the polar bears. Yet the loss of pteropods would impact our lives much more directly. Puny though they are, pteropods are a major food source of some of the biggest cash cows in the sea—salmon, herring, cod, and pollack. A significant decline in their population, Fabry says, could have grave economic consequences.

What do pteropods eat? Put a drop of seawater on a slide under a microscope and you will see: amoebas, tiny crustaceans, and plankton, many of which also sport shells. A major thrust of current research is to understand how creatures like these at the bottom of the food chain respond to ocean acidification. Toward that goal, scientists have scooped samples of seawater from a variety of latitudes and studied the rich broth of microorganisms they contain in simulator tanks built into the decks of ships. "The idea is to keep the specimens as fresh as possible in their natural habitat," explains David Hutchins, a biological oceanographer at the University of Southern California in Los Angeles. Then the simulation trials begin: The temperature, pH, and CO_2 levels of the tank are adjusted to mimic conditions expected a century from now.

What can Hutchins discern about the future from these simulations? There will be winners and losers, but the overall picture is, he says, "frightening."

As the temperature and acidity of a test tank climb, diatoms that dominate the cold northern oceans fall off steeply in number—an ominous sign, given that they currently support by far the richest fisheries in the world. The Bering Sea alone generates about 30 percent of the global harvest of seafood. In the frigid southern

A pteropod with wings extended. Below: Aerial view of the Great Barrier Reef.

TOP: RUSS HOPCROFT/UAF/COML. BOTTOM: DAVIDWALLPHOTO.COM

oceans, plankton species are different, but some have shells, and the trend is the same: Their populations rapidly decline. At both poles, organisms in decline are being replaced by plankton called flagellates. According to Hutchins, flagellates are not nearly as good at passing their stored energy up the food chain to fish and other higher life forms. "That's going to disrupt food chains that sustain the kinds of creatures we're used to seeing at the poles—sea lions, penguins, and whales—and instead promote a microbe-dominated community," he says.

THE GREAT BELCH OF DESTRUCTION

The anticipated impact on wildlife resembles a game of dominoes: After acidification has destabilized one species or ecosystem, the damage could ripple up and down the food chain. Especially worrisome is the fact that the shelled plankton under threat are efficient at storing CO_2. When the creatures that eat the plankton die, their shells and organic remains fall to the ocean floor, sequestering carbon in the deep water and sediments. "Cold-water planktons are powerful allies in preventing atmospheric CO_2 from climbing higher than it already is," Hutchins says.

Therefore, their rapid decline could quickly turn the planet hotter. "Currently the ocean is a sink for CO_2—that is, it takes in more CO_2

The Cost on the STREET

The oceans will pay a devastating price for acidification, but we will be pummeled on land as well. Sectors at risk include:

Tourism. In Australia, almost 2 million visitors a year flock to the Great Barrier Reef, spending $4.8 billion, a significant percentage of the country's tourism income. Worldwide, so-called reef tourism is increasing at a rate of 20 percent a year, providing up to 25 percent of total gross domestic product for numerous island nations, particularly in the Caribbean.

Coastal communities. Studies have shown that reefs shield people, infrastructure, and lagoon ecosystems from wave and storm surges. With the disappearance of the reefs, hurricanes and other tropical storms will result in even greater loss of life and resources than is the case today.

Pharmaceuticals. Acidification's assault on marine biodiversity means fewer chances to derive drugs like AZT, which came from the sea. Today dozens of ocean-derived drugs are in the research and development pipeline, including at least 30 for the treatment of cancer. If acidification proceeds, "we may never get a chance to develop the next wonder drug," Canadian coastal economist Jack Ruitenbeek says.

Fisheries. Globally, 38 million people are directly employed by fisheries or fish-related industries, and more than a billion people—mostly in the developing world—rely on fish as their main source of protein. Within the next two decades, marine biologist Robert Cowen says, the continued loss of fish from poor management and overexploitation "could translate into the starvation of 100 million or 200 million people—and that's without ocean acidification." The added insult of more corrosive waters on already-depleted fish stocks, he says, could have reverberations for poor coastal inhabitants that are frankly alarming. **C. B.**

from the atmosphere than it releases," Hutchins explains. "But a warming and acidifying ocean could become a net source of CO_2." In other words, the world's seas could begin belching the gas into the atmosphere, just as our cars and factories do. In his opinion, that could unfold within a few centuries. "It's hard not to be negative about this," Hutchins says. "Frankly, ocean acidification is apocalyptic in its impact."

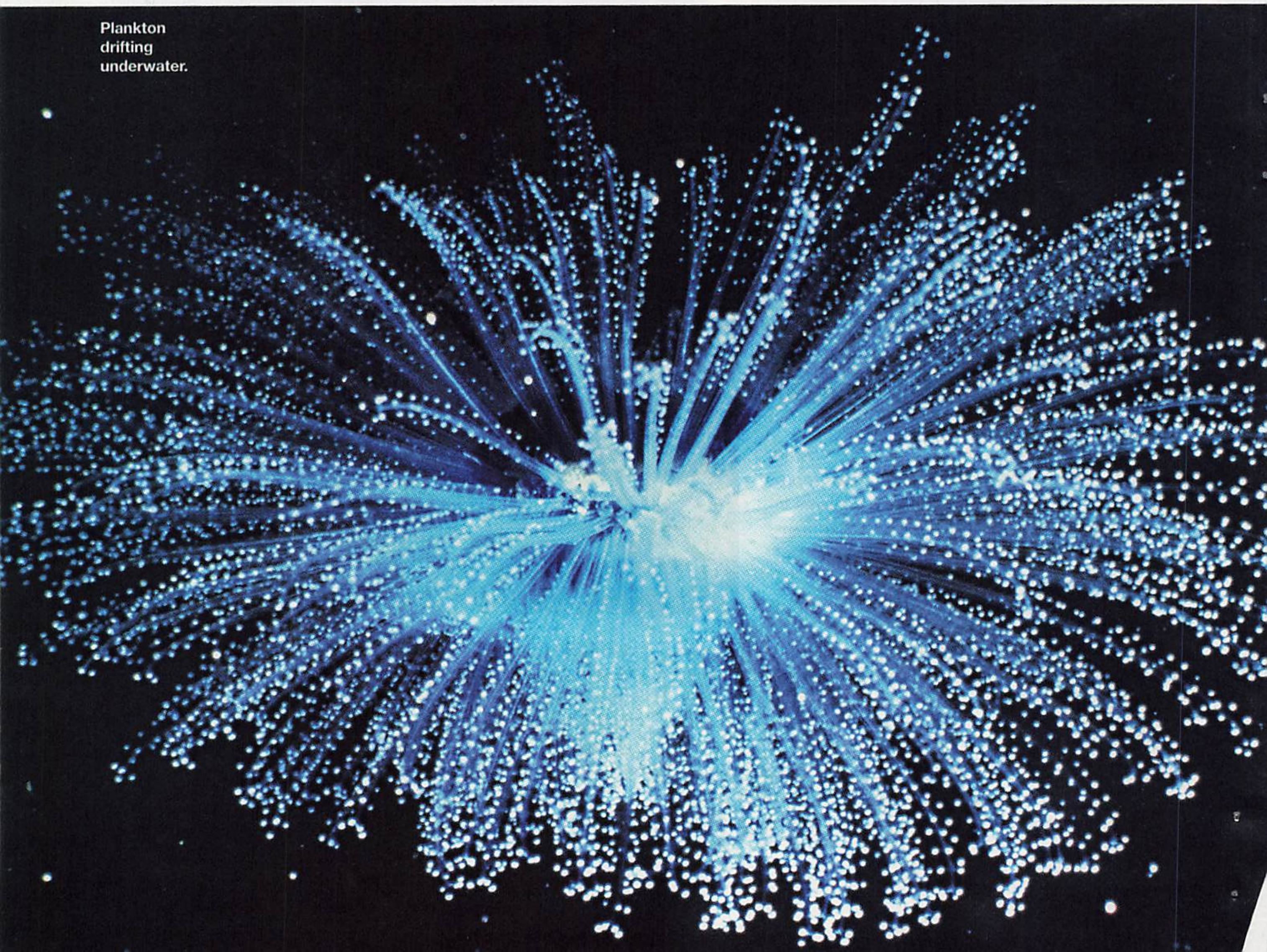
Robert Cowen, chairman of the division of marine biology and fisheries at the Rosenstiel School of Marine and Atmospheric Science, agrees, but for a different reason. His chief concern is fish populations, which were in steep decline even before ocean acidification was recognized. In just the past 40 years, overfishing, destructive trawling, and poor management of the seas have depleted 75 percent of our commercially important fish stocks, with almost one-third of them—including tuna, marlin, and shark—under particular threat. "We're hammering fish from the top down and now from the bottom up as more acidic oceans erode the base of the food chain," Cowen says.

It was at a conference two years ago, Cowen adds, that the scale of the disaster unfolding at sea really hit him. Deeply disturbed, he and his wife, Su Sponaugle, also a marine biologist at Rosenstiel, soon realized they would have to tone down how they talked about the research in front of their adolescent twins. "They overheard one of our conversations and started asking questions like 'What's going to happen?'" Sponaugle recalls. "We could see their distress and hear the agitation in their voices, and then they wanted to know, 'Is it too late?' and we're like, 'Hmm…well…'"

What Sponaugle and Cowen didn't want to say—or couldn't find the way to say—was yes, it might be too late. You can't turn an ocean liner on a dime, and in their view, it will take a complete about-face in society's profligate use of fossil fuels to avert a catastrophe. Nor are they alone in that opinion. "If we were to begin to reduce man-made emissions this year," NOAA's Feely says, "it would take decades before we'd see CO_2 levels and acidity start to go down instead of up and hundreds or thousands of years to return to pre-industrial levels."

Very simply, the process by which the ocean normally maintains its chemical equilibrium is glacially slow, severely limiting its capacity to adjust to an extreme shock. And make no mistake: The massive influx of industrial emissions is just that.

Over the history of the planet, there have been many sudden peaks in CO_2 related to volcanic eruptions, releases from hydrothermal vents, and other natural events. When the pH of the ocean dips as a result of absorbing this excess gas, bottom sediments rich in calcium carbonate begin to dissolve, countering the increase in acidity. This buffering process occurs over 20,000 years, roughly the



Plankton drifting underwater.

LARRY MADIN/GETTY IMAGES

Three Bold Plans to Save the SEAS

The bleak prognosis for marine species—and ultimately humans—in an environment of unchecked ocean acidification has prompted scientists to suggest a number of mitigation strategies.

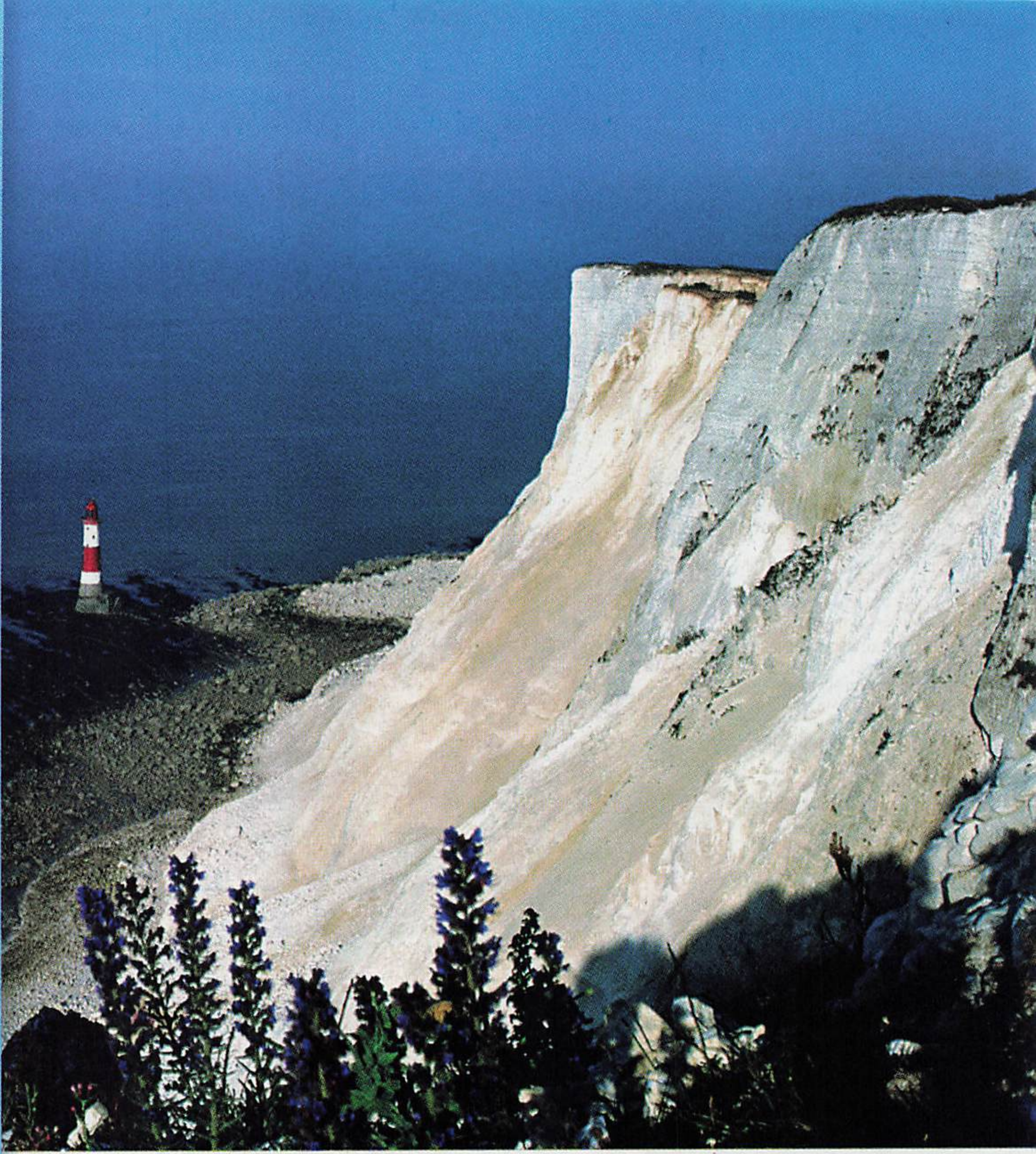
1. One proposal, first suggested in the late 1980s by oceanographer John Martin of the Moss Landing Marine Laboratories in California, involves seeding ocean surfaces with iron to promote phytoplankton blooms that will soak up carbon dioxide, eventually exporting it into the deep ocean. The plan has the added theoretical benefit of reducing atmospheric carbon. The first part of the process, the phytoplankton bloom, has already been demonstrated in small-scale tests in the South Pacific and the equatorial Pacific Ocean. But no one has ever shown that a carbon drawdown will persist over time, making many scientists fear that the effort could send the ocean's biochemical systems careering in unforeseen directions.

2. A second tactic under consideration at places like the Carnegie Institution of Washington and the University of California at Santa Cruz is to neutralize the seas—possibly with limestone from, say, the White Cliffs of Dover. But there are problems here as well: The scale of the mining and transportation effort to harvest these minerals would be enormous and extremely expensive. Moreover, it would itself involve the expenditure of large amounts of energy and thus the emission of additional carbon dioxide into the atmosphere.

3. Last year a team of scientists led by Kurt Zenz House, a doctoral candidate at Harvard University, proposed something they call engineered weathering, inspired by a natural process in which slightly acidic freshwater is neutralized by exposure to alkalizing minerals. Under House's proposal, hydrochloric acid would be harvested from the ocean by a specialized electrochemical treatment and then exposed to silicates, resulting in a net alkalizing shift.

When it comes to saving the seas, of course, the kind of technological fixes suggested here would be measures of last resort. Bärbel Hönisch, a marine biologist and geochemist at Columbia University's Lamont-Doherty Earth Observatory, points out that "none of these strategies has been tested over the long term, and the potential effects on the ecosystem are uncertain." In the end, she adds, the best solution might be the most obvious one: Dramatically reduce our carbon emissions. **C. B.**

TOP: DEXCHAMPS/ANDIA.FR/DRR.NET. BOTTOM: INTERNETWORK MEDIA/GETTY IMAGES



Can the White Cliffs of Dover (above) save the seas? If not, the plankton bloom seen in the Atlantic, below, might become a thing of the past.

time it takes for water to circulate along the bottom from the Atlantic to the Pacific and back up to the surface several times. Currently, however, we are pouring man-made CO_2 into the atmosphere at 50 times the natural rate. "That overwhelms the natural buffering system for maintaining balance in ocean chemistry," the Carnegie Institution's Caldeira says. "To find any parallel in the earth's history you would have to look to a sudden violent shock to the system far in the geologic past."

One such event occurred 55 million years ago at the so-called Paleocene-Eocene Thermal Maximum (PETM), when 4.5 million tons of greenhouse gases were released into the atmosphere. Just what triggered this enormous emission is not known, but scientists suspect volcanic activity may have begun the process. That may in turn have caused the planet to heat up enough to melt deposits of methane frozen in sediments on the ocean floor (something, incidentally, that could happen again), discharging even more potent greenhouse gases into the atmosphere and further heating the planet in an escalating feedback loop.

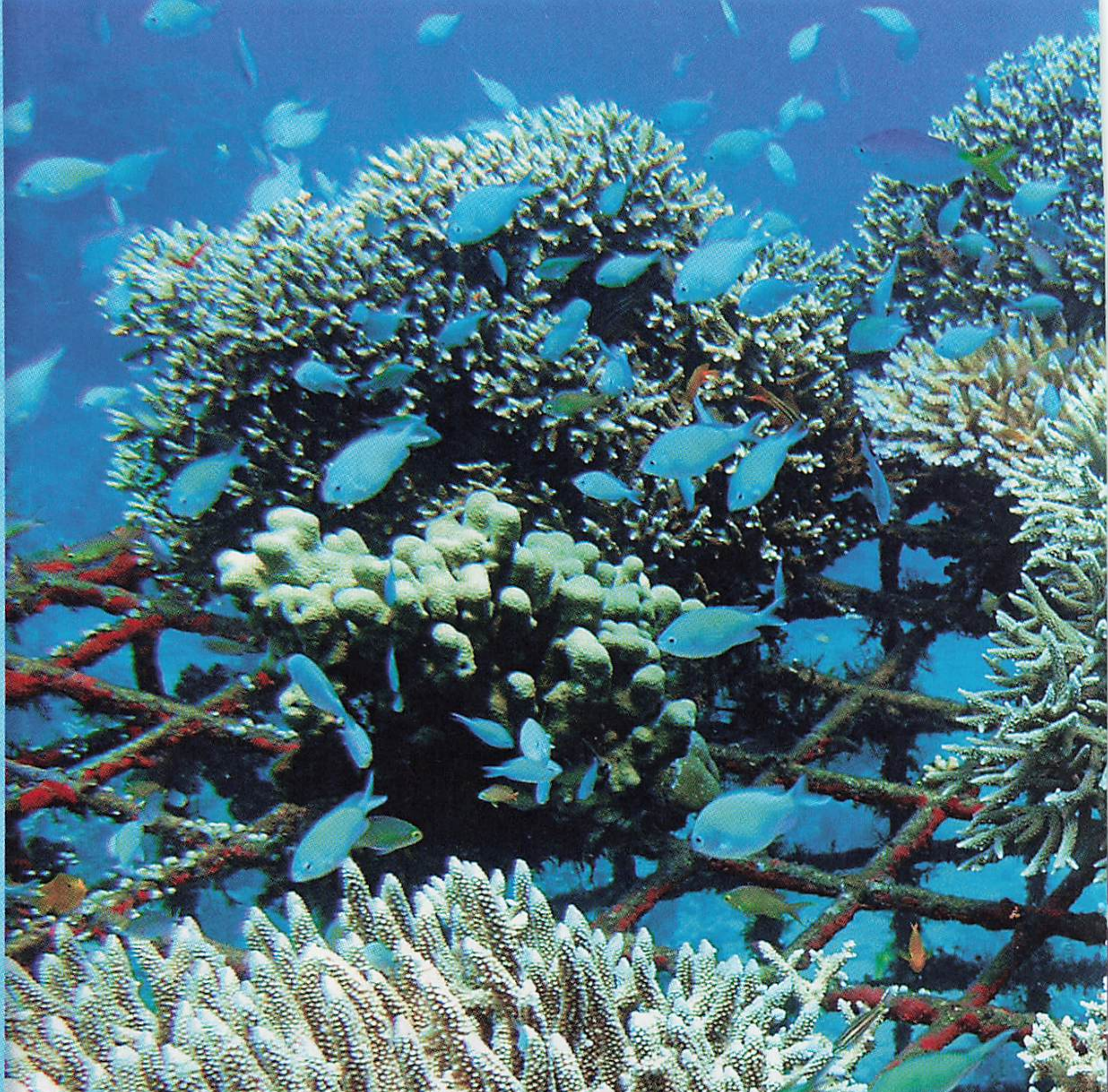
Whatever the exact cause of the CO_2 release at the PETM, the

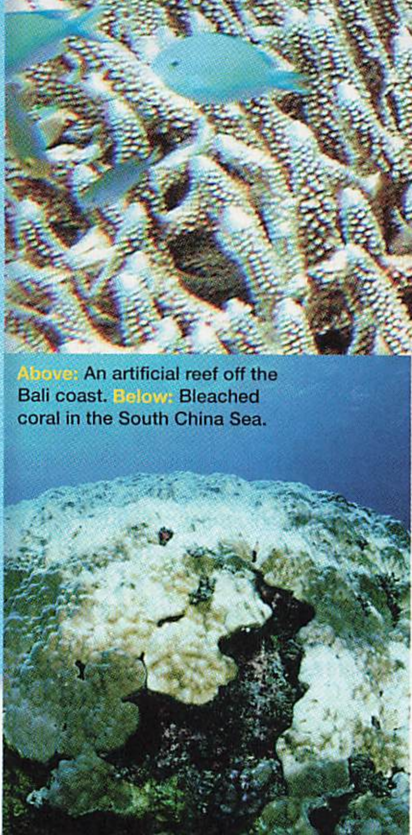
Rescuing the REEFS!

With reefs so endangered, you might think there is little you can personally do to help. But according to reef specialist Meaghan Johnson of the Nature Conservancy, individuals can make a difference here. "Anything we can do to reduce stress on coral reefs is a step in the right direction, and there is definitely a role for the public," she says. To that end, the conservancy and other groups suggest that you:

- Reduce your personal carbon footprint. The less fossil fuel you use, the less carbon you release into the atmosphere and the less you contribute to the twin threats of global warming and ocean acidification. Take public transportation instead of a car, and, if possible, opt for green power like solar or wind at home.
- Eat low on the food chain (we use less energy producing a salad than a steak).
- Conserve water, creating less runoff and wastewater to pollute the ocean.
- Use organic fertilizers in your garden. The chemicals from commercial fertilizers will eventually find their way into the ocean, further harming the reefs.
- Plant trees. They absorb carbon dioxide and reduce runoff.
- Visit a reef, but don't consume it. If you vacation at a reef resort, patronize businesses that manage the reefs responsibly (ask about the groups' eco policies), and don't buy souvenirs plundered from the reef ecosystem. Also, practice responsible diving and snorkeling: Don't touch the reef or anchor your boat on the reef, acts that can damage or even kill these ecosystems.

While you are doing your part, scientists like Johnson, a participant in the Florida Reef Resilience Program, hope the reefs can be restored through careful monitoring and protection of reef nurseries. Another effort, called Biorock, comes from the late architect Wolf Hilbertz and coral scientist Tom Goreau. To restore the reefs, latticed steel structures are lowered into flagging reef habitats like the one at right and exposed to electric current. The current promotes the crystallization of dissolved minerals, forming limestone deposits that cling to the structure. Natural reef fragments are transplanted onto the lattice, and coral larvae flock to the limestone. They are quickly followed by the rest of the usual reef denizens—urchins, crabs, fish, and lobsters. The technique has so far been successfully deployed in Panama, Thailand, Indonesia, French Polynesia, and the Philippines. **C. B.**





Above: An artificial reef off the Bali coast. Below: Bleached coral in the South China Sea.

TOP: WOLF HILBERTZ/GLOBALCORAL.ORG. BOTTOM: NEWSCOM

earth warmed faster than at almost any other time in its history. The average temperature soared 9 degrees Fahrenheit, entire ecosystems shifted to higher latitudes, and massive extinctions occurred on land and, most telling, at sea. The abrupt rise of CO_2 acidified the oceans. James Zachos, a paleo-oceanographer from the University of California at Santa Cruz, analyzed sediment cores obtained from deep drilling in the ocean and discovered that bottom-dwelling creatures with shells disappeared from the fossil record for a period of more than 40,000 years corresponding to the PETM. And once the oceans turned more acidic, Zachos says, they did not recover

quickly: It took another 60,000 years before sediments again began to show a thick white streak indicative of fossilized shells.

Drastic as the PETM was, the event is tame compared with acidification today. "Back then," Zachos says, "4.5 million tons of CO_2 were released over a period of 1,000 to 10,000 years. Industrial activities will release the same amount in a mere 300 years—so quickly that the ocean's buffering system doesn't even come into play."

This is not to imply that current CO_2 emissions are likely to kill off all life in the sea. Microbes, with their rapid generation times, should evolve and ultimately persist in altered seas. But slower-to-reproduce creatures such as fish and other higher organisms will struggle to survive. "The marine ecosystem will adapt," USC's Hutchins believes. Life may be different, but it will go on.

Kleypas of NCAR stands out among marine biologists in her optimism that we will be able to stop the output of man-made CO_2 in time to prevent irreparable harm to the marine ecosystem. To do that, she acknowledges, will take incredible sacrifice and an overhaul of infrastructure on an unprecedented scale. "I know people think I'm crazy," she says, "but we're the only species that can change our behavior overnight." ■

THE DISCOVER INTERVIEW

MAX TEGMARK

His grand theory posits parallel worlds in multiple dimensions of space and time, infinite realms where our doppelgängers live alternate lives.

BY **ADAM FRANK** PHOTOGRAPHY **BY ERIKA LARSEN**

Cosmologists are not your run-of-the-mill thinkers, and Max Tegmark is not your run-of-the-mill cosmologist. Throughout his career, Tegmark has made important contributions to problems such as measuring dark matter in the cosmos and understanding how light from the early universe informs models of the Big Bang. But unlike most other physicists, who stay within the confines of the latest theories and measurements, the Swedish-born Tegmark has a night job. In a series of papers that have caught the attention of physicists and philosophers around the world, he explores not what the laws of nature say but why there are any laws at all.

According to Tegmark, "there is only mathematics; that is all that exists." In his theory, the mathematical universe hypothesis, he updates quantum physics and cosmology with the concept of many parallel universes inhabiting multiple levels of space and time. By posing his hypothesis at the crossroads of philosophy and physics, Tegmark is harking back to the ancient Greeks with the oldest of the old questions: What is real?

Tegmark has pursued this work despite some risk to his career. It took four tries before he could get an early version of the mathematical universe hypothesis published, and when the article finally appeared, an older colleague warned that his "crackpot ideas" could damage his reputation. But propelled by optimism and passion, he pushed on.

"I learned pretty early that if I focused exclusively on these big questions I'd end up working at McDonald's," Tegmark explains. "So I developed this Dr. Jekyll/Mr. Hyde strategy where officially, whenever I applied for jobs, I put forth my mainstream work. And then quietly, on the side, I pursued more philosophical interests." The strategy worked. Today a professor at the Massachusetts Institute of Technology, Tegmark travels among the world's top physicists. Backed by this well-earned credibility, his audacious ideas are sparking fascination and taking flight.

These days Tegmark is a busy man. With his wife, the Brazilian cosmologist Angelica de Oliveira-Costa, he balances science with the demands of raising two young boys. Our interviewer, theoretical astrophysicist Adam Frank of the University of Rochester in New York, finally caught up with Tegmark as he made his way home to Winchester, Massachusetts, from a conference at Stanford University. In a comic juxtaposition of the profound and the profane, they spoke about the nature of reality by cell phone for three hours as Tegmark

jockeyed his way through an airport rental car return, security lines, and a long wait for a delayed flight. A riff on reality would brake to a halt so Tegmark could avoid being hit by a rental-agency van. Just as the conversation plunged into parallel universes, Tegmark would have to downshift the dialogue for the bewildered security guard checking his boarding pass. Tegmark's infectious excitement over the big issues, from physics and philosophy to kids and cosmology, made for one hell of an afternoon's ride.

Max, you have gained a reputation for thinking far outside the box even for a cosmologist. Have you always pondered deep questions of Life, the Universe, and Everything?
No. I was a very confused youth. I came to it all pretty late, and there was no one I talked about philosophy with as a teenager. I did have one friend in high school who did everything the opposite way from everyone else. If people were sending letters in rectangular envelopes, he would make triangular envelopes and send letters in those. I remember thinking, "That is cool. That is how I want to be."

Is that why you decided to go into physics?
Actually, my dad is a mathematician, and he was always very encouraging about math, but physics was my single most boring subject in high school. So I began as an undergrad in economics.

That was an interesting choice.... When did physics show up on your radar screen again?
A friend gave me a book, *Surely You're Joking, Mr. Feynman!* by the physicist Richard Feynman. It was all about picking locks and picking up women. It had nothing to do with physics, but it struck me how between the lines it said loud and clear, *"I love physics!"* I couldn't understand how this could be the same boring stuff from high school. It really piqued my curiosity.

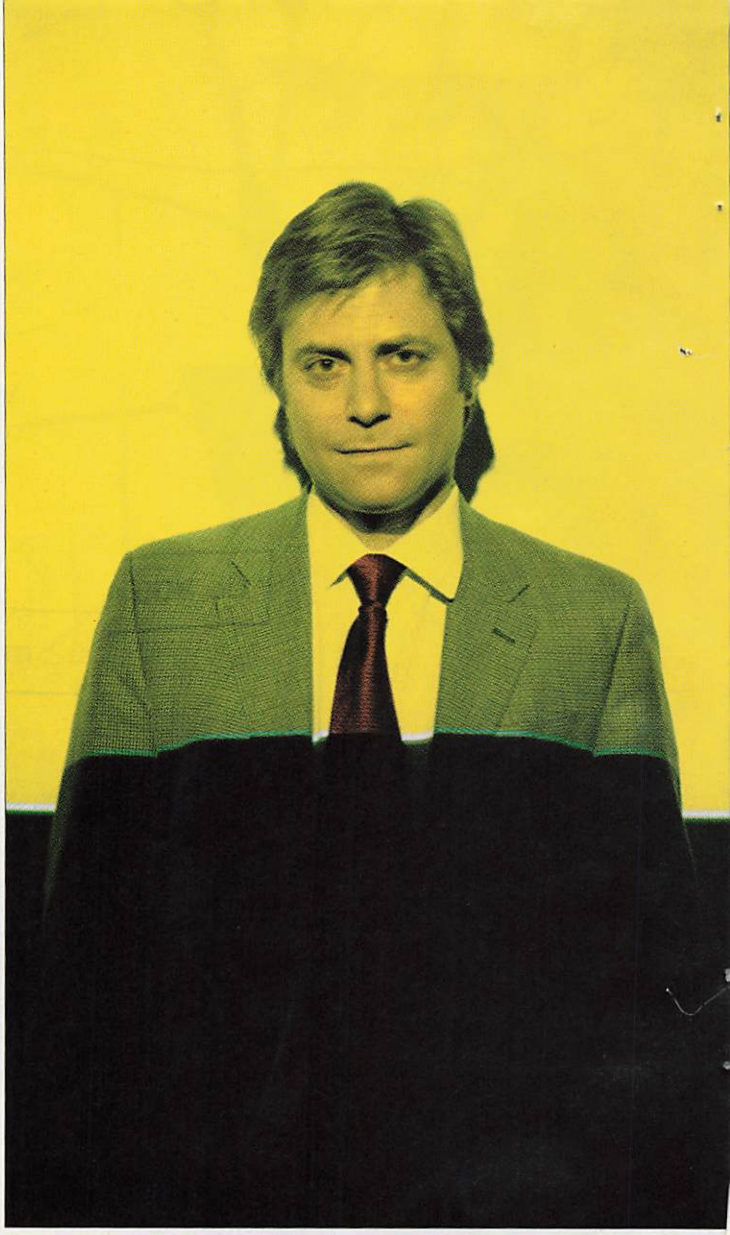
How so?
If you see some mediocre guy walking down the street arm in arm with Cameron Diaz, you say to yourself, "I'm missing something here." So I started reading Feynman's *Lectures on Physics* and I was like, whoa! Why haven't I realized this before?

So then you changed your major?
Umm, no. You don't pay for college in Sweden, so I was able to do this kind of scam where I enrolled in a different university to do physics without telling them I was already in college for economics.

You were in two colleges at the same time?
Yeah. You can see I was confused. It got complicated at times. I would have exams in both places on the same day, and I'd have to bike really fast between them.

Was it in college that you started to think about the bigger questions?
I was taking the one and only quantum physics class offered, and when I got to the chapter on measurement I felt sure that I was missing something.

You're talking about the way the observer appears to affect the measurement of what's being observed.
Right. There is this beautiful mathematical equation in quantum theory called the Schrödinger equation. It uses something called the wave function to describe the system you are studying—an atom, an electron, whatever—and all the possible ways that system can evolve. The usual perspective of quantum mechanics is that as soon as you measure something, the wave function literally collapses, going from a state that reflects all potential outcomes to a state that reflects only one: the outcome you see at the moment the measurement is done. It seemed crazy to me. I didn't get why you were supposed to use the Schrödinger equation before you measured the atom, but then, while you're measuring it, the equation doesn't apply. So I got up my courage and knocked on the door of one of the most famous physicists in Sweden, a man on the Nobel committee, but he just blew me off. It wasn't until years later that I had this revelation that it wasn't me who didn't get it; it was him!



Go far enough out and you will find another Earth with another version of yourself.

INSET: JPL-CALTECH/NASA

It is a beautiful moment in the education of a scientist when you realize that these guys in higher positions of power still don't have all of the answers. So you took your questions about the Schrödinger equation and the effect of measurement with you when you left for the United States and your Ph.D. at Berkeley?
That's where it all started for me. I had this friend, Bill Poirier, and we spent hours talking about crazy ideas in physics. He was ribbing me because I argued that any fundamental description of the universe should be simple. To annoy him, I said there could be a whole universe that is nothing more than a dodecahedron, a 12-sided figure the Greeks described 2,500 years ago. Of course, I was just fooling around, but later, when I thought more about it, I got excited about the idea that the universe is really nothing more than a mathematical object. That got me thinking that every mathematical object is, in a sense, its own universe.

Right from the start you tried to get this radical idea of yours published. Were you worried about whether it would affect your career?
I anticipated problems and did not submit until I had accepted a postdoctoral appointment at Princeton University. My first paper got rejected by three journals. Finally I got a good referee report from *Annals of Physics,* but the editor there rejected the paper as being too speculative.

Wait—that is not supposed to happen. If the referee likes a paper, it usually gets accepted.
That's what I thought. I was fortunate to be friends with John Wheeler, a Princeton theoretical physicist and one of my greatest physics heroes, who recently passed away. When I showed him the rejection letter, he said, "'Extremely speculative'? Bah!" Then he reminded me that some of the original papers on quantum mechanics were also considered extremely speculative. So I wrote an appeal to *Annals of Physics* and included Wheeler's comments. Finally the editors there published it.

Still, it wasn't your bread and butter. You did your Ph.D. and postdoc in cosmology, a totally different subject.
It's ironic that my cover for these more philosophical interests was cosmology, a field that has often been seen as flaky as well. But cosmology was gradually becoming more respectable because computer technology, space technology, and detector technology had combined to give us an avalanche of great information about the universe.

Let's talk about your effort to understand the measurement problem by positing parallel universes—or, as you call them in aggregate, the multiverse. Can you explain parallel universes?
There are four different levels of multiverse. Three of them have been proposed by other people, and I've added a fourth—the mathematical universe.

What is the multiverse's first level?
The level I multiverse is simply an infinite space. The space is infinite, but it is not infinitely old—it's only 14 billion years old, dating to our Big Bang. That's why we can't see all of space but only part of it—the part from which light has had time to get here so far. Light hasn't had time to get here from everywhere. But if space goes on forever, then there must be other regions like ours—in fact, an infinite number of them. No matter how unlikely it is to have another planet just like Earth, we know that in an infinite universe it is bound to happen again.

You're saying that we must all have doppelgängers somewhere out there due to the mathematics of infinity.
That's pretty crazy, right? But I'm not even asking you to believe in anything weird yet. I'm not even asking you to believe in any kind of crazy new physics. All you need for a level I multiverse is an infinite universe—go far enough out and you will find another Earth with another version of yourself.

So we are just at level I. What's the next level of the multiverse?
Level II emerges if the fundamental equations of physics, the ones that govern the behavior of the universe after the Big Bang, have more than one solution. It's like water, which can be a solid, a liquid, or a gas. In string theory, there may be 10^{500} kinds or even infinitely many kinds of universes possible. Of course string theory might be wrong, but it's perfectly plausible that whatever you replace it with will also have many solutions.

Why should there be more than one kind of universe coming out of the Big Bang?
Inflationary cosmology, which is our best theory for what happened right after the Big Bang, says that a tiny chunk of space underwent a period of rapid expansion to become our universe. That became our level I multiverse. But other chunks could have inflated too, from other Big Bangs. These would be parallel universes with different kinds of physical laws, different solutions to those equations. This kind of parallel universe is very different from what happens in level I.

Why?
Well, in level I, students in different parallel universes might learn a different history from our own, but their physics would still be the same. Students in level II parallel universes learn different history and different physics. They might learn that there are 67 stable elements in the periodic table, not the 80 we have. Or they might learn there are four kinds of quarks rather than the six kinds we have in our world.

Do these level II universes inhabit different dimensions?
No, they share the same space, but we could never communicate with them because we are all being swept away from each other as space expands faster than light can travel.

OK, on to level III.
Level III comes from a radical solution to the measurement problem proposed by a physicist named Hugh Everett back in the 1950s. [Everett left physics after completing his Ph.D. at Princeton because of a lackluster response to his theories.] Everett said that every time a measurement is made, the universe splits off into parallel versions of itself. In one universe you see result A on the measuring device, but in another universe, a parallel version of you reads off result B. After the measurement, there are going to be two of you.

So there are parallel me's in level III as well.
Sure. You are made up of quantum particles, so if they can be in two places at once, so can you. It's a controversial idea, of course, and

Parallel universes are like different pages in a book, existing independently, simultaneously, and right next to each other.

people love to argue about it, but this "many worlds" interpretation, as it is called, keeps the integrity of the mathematics. In Everett's view, the wave function doesn't collapse, and the Schrödinger equation always holds.

The level I and level II multiverses all exist in the same spatial dimensions as our own. Is this true of level III?

No. The parallel universes of level III exist in an abstract mathematical structure called Hilbert space, which can have infinite spatial dimensions. Each universe is real, but each one exists in different dimensions of this Hilbert space. The parallel universes are like different pages in a book, existing independently, simultaneously, and right next to each other. In a way all these infinite level III universes exist right here, right now.

That brings us to the last level: the level IV multiverse intimately tied up with your mathematical universe, the "crackpot idea" you were once warned against. Perhaps we should start there.

I begin with something more basic. You can call it the external reality hypothesis, which is the assumption that there is a reality out there that is independent of us. I think most physicists would agree with this idea.

The question then becomes, what is the nature of this external reality?

If a reality exists independently of us, it must be free from the language that we use to describe it. There should be no human baggage.

I see where you're heading. Without these descriptors, we're left with only math.

The physicist Eugene Wigner wrote a famous essay in the 1960s called "The Unreasonable Effectiveness of Mathematics in the Natural Sciences." In that essay he asked why nature is so accurately described by mathematics. The question did not start with him. As far back as Pythagoras in the ancient Greek era, there was the idea that the universe was built on mathematics. In the 17th century Galileo eloquently wrote that nature is a "grand book" that is "written in the language of mathematics." Then, of course, there was the great Greek philosopher Plato, who said the objects of mathematics really exist.

How does your mathematical universe hypothesis fit in?

Well, Galileo and Wigner and lots of other scientists would argue that abstract mathematics "describes" reality. Plato would say that mathematics exists somewhere out there as an ideal reality. I am working in between. I have this sort of crazy-sounding idea that the reason why mathematics is so effective at describing reality is that it *is* reality. That is the mathematical universe hypothesis: Mathematical things actually exist, and they are actually physical reality.

OK, but what do you mean when you say the universe is mathematics? I don't feel like a bunch of equations. My breakfast seemed pretty solid. Most people will have a hard time accepting that their fundamental existence turns out to be the subject they hated in high school.

For most people, mathematics seems either like a sadistic form of punishment or a bag of tricks for manipulating numbers. But like physics, mathematics has evolved to ask broad questions.These days mathematicians think of their field as the study of "mathematical structures," sets of abstract entities and the relations between them. What has happened in physics is that over the years more complicated and sophisticated mathematical structures have proved to be invaluable.

Can you give a simple example of a mathematical structure?

The integers 1, 2, 3 are a mathematical structure if you include operations like addition, subtraction, and the like. Of course, the integers are pretty simple. The mathematical structure that must be our universe would be complex enough for creatures like us to exist. Some people think string theory is the ultimate theory of the universe, the so-called theory of everything. If that turns out to be true, then string theory will be a mathematical structure complex enough so that self-awareness can exist within it.

But self-awareness includes the feeling of being alive. That seems pretty hard to capture in mathematics.

To understand the concept, you have to distinguish two ways of viewing reality. The first is from the outside, like the overview of a physicist studying its mathematical structure. The second way is the inside view of an observer living in the structure. You can think of a frog living in the landscape as the inside view and a high-flying bird surveying the landscape as the outside view. These two perspectives are connected to each other through time.

In what way does time provide a bridge between the two perspectives?

Well, all mathematical structures are abstract, immutable entities. The integers and their relations to each other, all these things exist outside of time.

Do you mean that there is no such thing as time for these structures?

Yes, from the outside. But you can have time inside some of them. The integers are not a mathematical structure that includes time, but Einstein's beautiful theory of relativity certainly does have parts that correspond to time. Einstein's theory has a four-dimensional mathematical structure called space-time, in which there are three dimensions of space and one dimension of time.

So the mathematical structure that is the theory of relativity has a piece that explicitly describes time or, better yet, *is* time. But the integers don't have anything similar.

Yes, and the important thing to remember is that Einstein's theory taken as a whole represents the bird's perspective. In relativity all of time already exists. All events, including your entire life, already exist as the mathematical structure called space-time. In space-time, nothing happens or changes because it contains all time at once. From the frog's perspective it appears that time is flowing, but that is just an illusion. The frog looks out and sees the moon in space, orbiting around Earth. But from the bird's perspective, the moon's orbit is a static spiral in space-time.

The frog feels time pass, but from the bird's perspective it's all just one eternal, unalterable mathematical structure.
That is it. If the history of our universe were a movie, the mathematical structure would correspond not to a single frame but to the entire DVD. That explains how change can be an illusion.

Of course, quantum mechanics with its notorious uncertainty principle and its Schrödinger equation will have to be part of the theory of everything.
Right. Things are more complicated than just relativity. If Einstein's theory described all of physics, then all events would be predetermined. But thanks to quantum mechanics, it's more interesting.

But why do some equations describe our universe so perfectly and others not so much?
Stephen Hawking once asked it this way: "What is it that breathes fire into the equations and makes a universe for them to describe?" If I am right and the cosmos is just mathematics, then no fire-breathing is required. A mathematical structure doesn't describe a universe, it is a universe. The existence of the level IV multiverse also answers another question that has bothered people for a long time. John Wheeler put it this way: Even if we found equations that describe our universe perfectly, then why these particular equations and not others? The answer is that the other equations govern other, parallel universes, and that our universe has these particular equations because they are just statistically likely, given the distribution of mathematical structures that can support observers like us.

These are pretty broad and sweeping ideas. Are they just philosophical musings, or is there something that can actually be tested?
Well, the hypothesis predicts a lot more to reality than we thought, since every mathematical structure is another universe. Just as our sun is not the center of the galaxy but just another star, so too our universe is just another mathematical structure in a cosmos full of mathematical structures. From that we can make all kinds of predictions.

So instead of exploring just our universe, you look to all possible mathematical structures in this much bigger cosmos.
If the mathematical universe hypothesis is true, then we aren't asking which particular mathematical equations describe all of reality anymore. Instead we have to figure out how to separate the frog's view of the universe—our observations—from the bird's view. Once we distinguish them we can determine whether we have uncovered the true structure of our universe and figure out which corner of the mathematical cosmos is our home.

Max, this is pretty rarefied territory. On a personal level, how do you reconcile this pursuit of ultimate truth with your everyday life?
Sometimes it's quite comical. I will be thinking about the ultimate nature of reality and then my wife says, "Hey, you forgot to take out the trash." The big picture and the little picture just collide.

Your wife is a respected cosmologist herself. Do you ever talk about this over breakfast cereal with your kids?
She makes fun of me for my philosophical "bananas stuff," but we try not to talk about it too much. We have our kids to raise.

Do your theories help with raising your kids, or does that also seem like two different worlds?
The overlap with the kids is great because they ask the same questions I do. I did a presentation about space for my son Alexander's preschool when he was 4. I showed them videos of the moon landing and brought in a rocket. Then one little kid put up his hand and said: "I have a question. Does space end or go on forever?" I was like, "Yeah, that is exactly what I am thinking about now." ■

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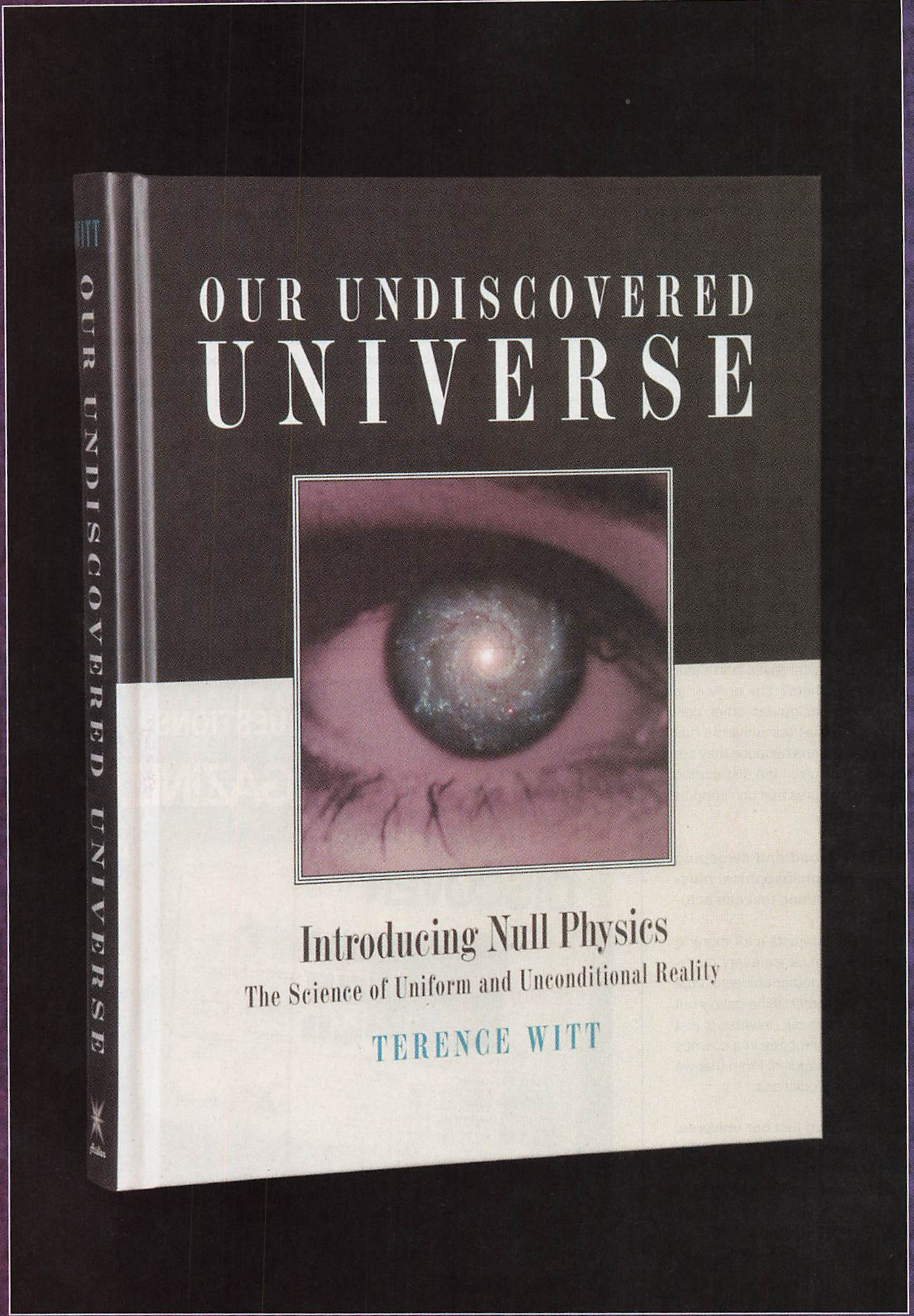

OUR UNDISCOVERED
UNIVERSE
Introducing Null Physics
The Science of Uniform and Unconditional Reality
TERENCE WITT
WITT
OUR UNDISCOVERED UNIVERSE

Theoretical physics has been hopelessly stalled for over 30 years. Moribund. Ossified. The Standard Model of particle physics uses over 20 ad hoc constants, and no one knows why they are necessary or why they have the values they do. Quantum physics and general relativity remain utterly incompatible. Cosmologists haven't the foggiest idea what could have caused the Big Bang or what, if anything, came before it. And finally, after over 30 years of effort, string theory hasn't even achieved the status of *science*.

There is a very simple reason for this catastrophic, intractable mess. Theorists stopped asking *why* a long time ago. Without the *why*, the search for mathematical symmetries becomes numerology, not science. No telescope or particle accelerator, regardless of its size, is going to tell us *why* the universe is the way it is. When the *why*'s remain unanswered, there is no understanding. When there is no understanding, there is no progress. But this sad situation is about to change forever.

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- Energy is a three-dimensional substance, and its most basic unit is time-distance^2.
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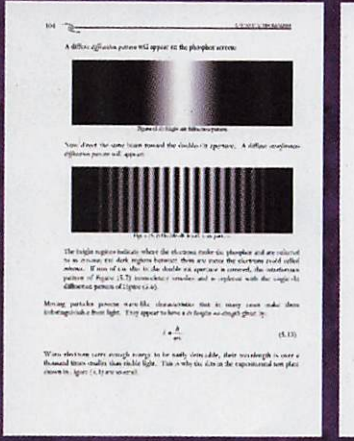

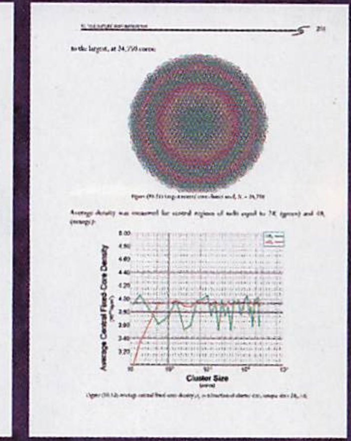

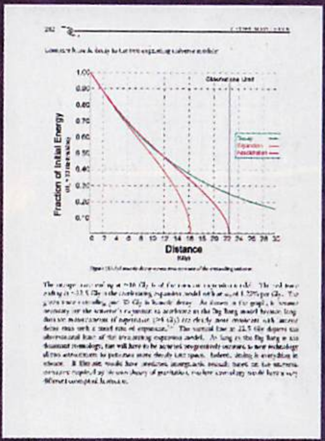

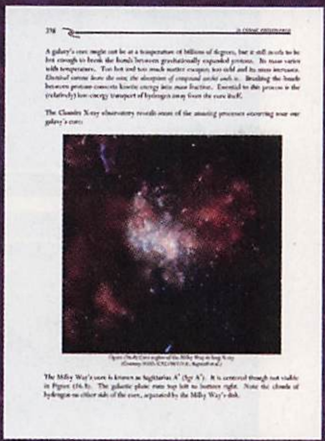

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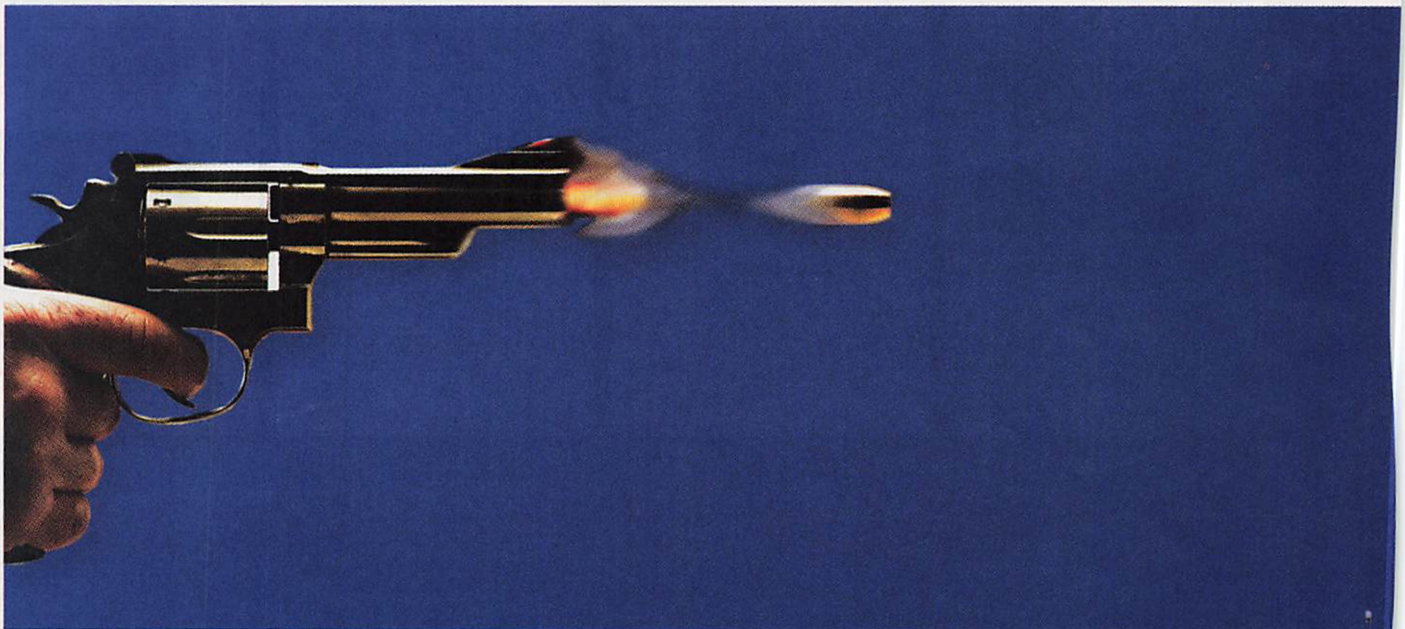
Medicine's MAGIC Bullets?

We trust today's miracle cures, but some have caused great harm. Who is to blame?

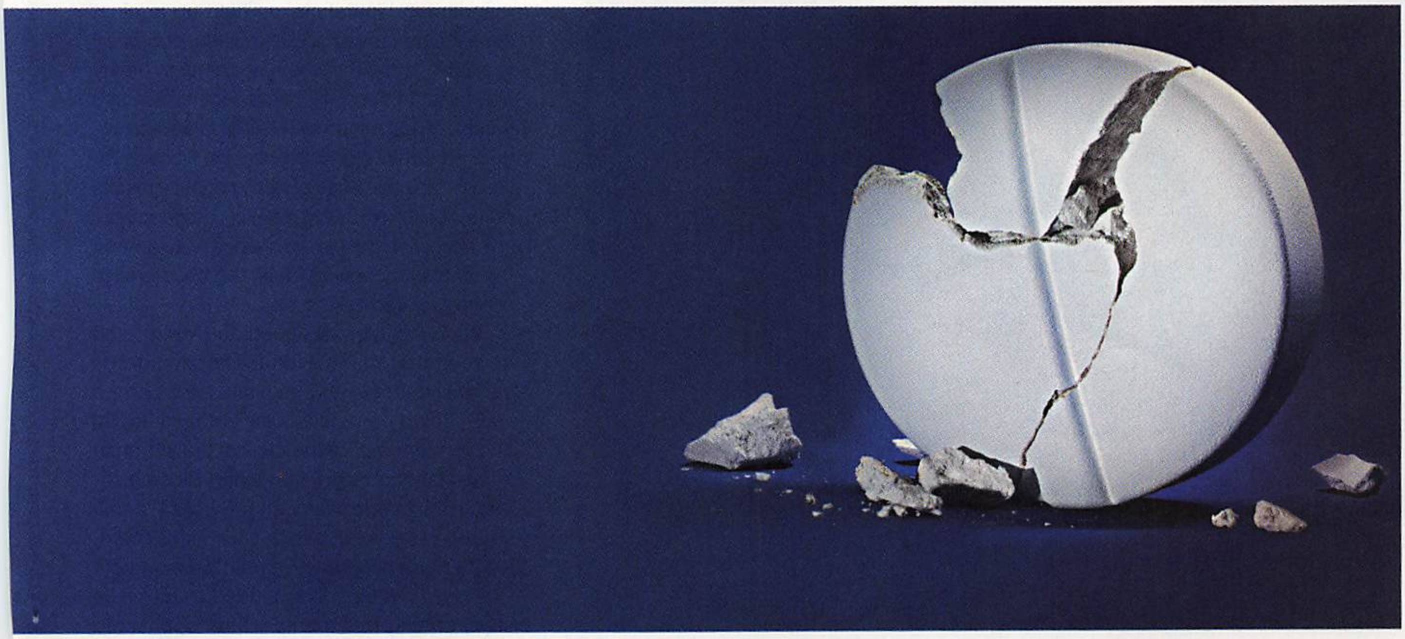


Phil Brewer thought he knew exactly what to do when the ambulance crew wheeled a well-dressed man in his late sixties into the emergency department. What he didn't know: He was about to be involved in a series of events that would kill his patient. Brewer, then an assistant professor of emergency medicine at Yale School of Medicine, had been alerted by the crew that the man, Sanders Tenant (a pseudonym), had suddenly begun to talk gibberish while dining out with his family. Then his right arm and leg had gone weak.

Brewer suspected an acute stroke, but first he had to rule out conditions that can masquerade as a stroke, such as low blood sugar, a seizure, a brain tumor, and migraine headache. He had only minutes to make the correct diagnosis. Then the gathering medical team would decide whether to use a new stroke treatment that had recently been approved, a clot-buster known as tPA. Brewer called in a neurologist and the stroke team. After a CAT scan of the patient's brain showed no sign of bleeding (something that would prevent the use of a clot-buster), the decision was made: Yes, use tPA. Despite following each step of the established protocol for this new treatment, Brewer experienced the unthinkable—his patient's death. Tenant suffered a massive brain hemorrhage and died, not from his stroke but from effects of tPA, the drug that was meant to save him.

When we go to the doctor, we assume that the drugs he or she prescribes have been carefully tested to make sure they are both safe and effective. Most times they are. Yet sometimes the drugs cause more problems than they solve. Adverse drug reactions kill tens of thousands of people annually; one widely cited study published in the *Journal of the American Medical Association* (*JAMA*) in 1998 puts the number at more than 100,000. Recently a series of drug recalls have pulled back the curtain to show how the media, the public, and some doctors can misinterpret medical studies or take them out of context in ways that make medical treatments look safer

BY **JEANNE LENZER**



How do today's medical

and more effective than they actually are.

To a greater degree than ever before, powerful forces in the marketplace are impacting the quality, use, and safety of prescription medications. Drug manufacturers are spending more to promote their products while being subjected to tighter regulation and greater pressure for financial returns. The media are talking up each new "miracle cure" in headlines and television segments. Doctors have to navigate a tangle of administrative and medical concerns, one physician noting that "if you have a patient in your office, you can't say, 'Oh, I'm going to look at the drug company's online database about Zyprexa.' Most doctors don't even know the databases exist. But even if they did, the next thing you know, three or four hours have gone by and you've missed all the patients waiting to see you." Insurance companies and even the stock market play a role too. And consumers, increasingly subject to pharmaceutical advertising, are routinely urged to demand the best and the newest for their health. All together, this is a perfect storm for prescription drug problems.

How often do today's medical "breakthroughs" become tomorrow's discredited science? John P. A. Ioannidis, an epidemiologist at Tufts University School of Medicine in Boston and the University of Ioannina School of Medicine in Greece, studied the question. He examined the most-cited clinical studies published in the top three medical journals between 1990 and 2000 to see how well researchers' initial claims held up against subsequent research. His findings, published in *JAMA,* show that the key claims of nearly one-third (14 out of 49) of the original research studies he examined were either false or exaggerated. Small study size, design flaws, publication bias (failure to publish negative results or duplication of positive results), drug-industry influence, and the play of chance were among the problems Ioannidis found that caused false or exaggerated claims.

Studies can be designed and interpreted in ways that make even ineffective drugs seem like lifesavers, says Curt Furberg, a well-known cardiovascular epidemiologist and former chief of the clinical trials branch at the National Heart, Lung, and Blood Institute in Bethesda, Maryland. Furberg, a tall, square-faced man with a Swedish accent, wants more objectivity in medical research. "We need more publicly funded studies," he says, adding that manufacturer-sponsored

PREVIOUS PAGES, FROM LEFT: COLIN ANDERSON/CORBIS; DAN SAELINGER. THIS PAGE: MARKUSSONPHOTO/GETTY IMAGES

“breakthroughs” become tomorrow’s discredited science?

research tends to minimize risks and exaggerate benefits.

A score of studies support his opinion. Among them is a 2003 analysis by Cary P. Gross, an associate professor of medicine at Yale School of Medicine, that was published in *JAMA*. In his survey, one study found that industry-sponsored research was positive 87 percent of the time compared with 65 percent positive for research that was not industry sponsored. According to Gross, the evidence was overwhelming that “industry sponsorship was likely to yield pro-industry results.” A 2006 analysis published in the *American Journal of Psychiatry* found that 90 percent of manufacturer-sponsored studies of antipsychotic drugs led to claims that the study drug was as good as, or superior to, every other drug in its class. Shannon Brownlee, an award-winning medical writer based in Washington, D.C., ascribed this to the “Lake Wobegon effect,” which renders every drug “above average.”

Furberg’s efforts to debunk overly enthusiastic interpretations of medical studies have led to occasional clashes with his colleagues. In 2004 the U.S. Food and Drug Administration (FDA) was preparing to hold hearings on the safety of painkillers known as COX-2 inhibitors, including Vioxx, which David Graham, an official in the FDA’s Office of Drug Safety, said may have caused an estimated 39,000 to 60,000 heart-attack deaths in just five years. At the time, Furberg was a member of the FDA Advisory Committee on Drug Safety and Risk Management. But after he told *The New York Times* that the COX-2 inhibitor Bextra also caused heart attacks, the agency made a surprising move: It removed Furberg from the advisory panel. Sandra Kweder, acting director of the Office of New Drugs, Center for Drug Evaluation and Research at the FDA, told a reporter that Furberg’s comments showed he could not be objective. Furberg now asks, “If bias was a concern, why did they allow 10 advisory members with ties to the manufacturers to be seated?” He was reinstated to the panel two days later and vindicated when the FDA announced that it had asked Pfizer to voluntarily withdraw Bextra from the market.

Part of the difficulty in detecting drug side effects, Furberg says, has to do with study size. Drugs go through a regimen of tests prior to receiving approval from the FDA. During the first two stages, called Phase I and II trials, an experimental drug is tested on just a few hundred volunteers to look for side effects. If no serious problems are detected, the drug is tested for efficacy in a Phase III trial. But efficacy trials often involve only several hundred to a few thousand patients. And while a study of 200 to 300 arthritis patients is large enough to show whether a new drug relieves pain, just one such study isn’t large enough to pick up less-common—but potentially deadly—side effects. Furberg says, “If only one in a thousand patients will die from a heart attack, an efficacy study of 200 or even 2,000 patients is simply too small to get a reliable answer about rare side effects.” Seemingly rare side effects can take tens of thousands of lives when millions of prescriptions are written.

Such limitations in a study’s design can escape detection even by top peer reviewers and medical editors. Marcia Angell, the former editor-in-chief of *The New England Journal of Medicine* (*NEJM*), says that most doctors are ill equipped to critically assess the conclusions of researchers. A trim woman with a warm smile, Angell leans forward in her seat at her home in Cambridge, Massachusetts, and says, “Let me tell you the dirty secret of medical journals: It is very hard to find enough articles to publish. With a rejection rate of 90 percent for original research, we were hard pressed to find 10 percent that were worth publishing. So you end up publishing weak studies because there is so much bad work out there.” Doctors, Angell says, are not skeptical enough about what they read in top journals. “They should say, ‘I don’t believe this; prove it to me.’ ”

The rest of the media don’t get any better marks. Gary Schwitzer, director of graduate studies in health journalism at the University of Minnesota School of Journalism, examined 400 medical news stories that were carried by 57 of the top print and broadcast media. “The majority failed to adequately discuss costs, quantify harms and benefits, and examine the quality of the studies,” Schwitzer says. Many quoted a sole source and failed to report potential financial conflicts. Schwitzer concluded that media reports give “a kid-in-the-candy-store portrayal, where everything is made to look amazing, harmless, and without a price tag.” Patients themselves “should not escape notice as willing collaborators, wishing for magic potions and taking drug company money to support consumer organizations,” Schwitzer continues.

Phil Brewer, the doctor whose stroke patient died after being treated with tPA, says media portrayals of new medicines are often “irrationally exuberant.” He points to a May 2007 article in *The New York Times* that he says typifies the problem. The article, about stroke victims, said that the clot-buster “tPA was shown in 1996 to save lives.” Yet in 2001, the American Heart Association (AHA) had withdrawn the claim that the drug “saves lives” from its promotion of tPA for stroke after the group was challenged to provide scientific evidence to support that claim. The AHA was also the subject of scrutiny when it was revealed that in the decade prior to its recommendation that doctors use tPA for stroke victims, the heart association had received $11 million from Genentech, tPA’s manufacturer.

The same *New York Times* article quoted a number of doctors saying that too few stroke patients were receiving tPA, yet failed to mention that many of these same doctors had received funding from Genentech. Nor did the article give a hint of the ferocious battle among doctors about the safety and efficacy of tPA: While a number of professional associations endorsed the drug, many others, such as the American Academy of Emergency Medicine, said it should not be considered the standard of care for acute stroke.

Asked about this reporting, Barbara Strauch, health editor of *The Times*, responded, “While some researchers had said in interviews that they believed the drug saved lives, our article incorrectly stated that the study had made that conclusion.” Strauch said the paper would publish a correction—which it did this past April, nearly a year later. (This was done in response to DISCOVER’s inquiries.) She added, “It is also true that some researchers quoted in the article, like many stroke researchers and many who study other diseases, are funded by and receive honoraria from the pharmaceutical industry. However, the main sources for our article were researchers at the National Institute of Neurological Disorders and Stroke (NINDS), who, the National Institutes of Health says, do not take money from drug manufacturers.”

“What you read in the media are these stories of a stroke patient getting tPA and miraculously improving within minutes,” Brewer says. “But we’ve all seen that happen in the ER, even before tPA was ever invented.” After his patient died, Brewer, wary of drawing conclusions on the basis of a single case, wanted to make sense of the data about tPA. Even though a landmark 1995 study conducted by NINDS

DON FARRALL/GETTY IMAGES

One way to make drugs look better or safer is to report only successful studies

showed that 12 to 13 of every 100 treated patients had less disability, Brewer says that "it was hard to put the conflicting [study] results together and determine whether the benefits really did outweigh the risks." So, like many physicians, he turned to the articles and analyses of Jerome Hoffman, a professor of medicine and emergency medicine at UCLA. "Dr. Hoffman has a brilliant mind," Brewer says. "He is listened to and trusted by more emergency physicians than anyone I know." An authority on medical studies, Hoffman, it turns out, was also the lone dissenting member of the AHA panel that recommended tPA for stroke.

Tall, white-haired, and wearing thick glasses, Hoffman looks the part of an elder statesman of medicine. He says he became interested in the interpretation of medical literature when he was just starting out as a resident physician at UCLA. He read studies and their interpretations voraciously, and eventually other physicians began coming to his talks to residents and medical students on how to interpret the medical literature. "Some studies just didn't make sense to me," he says. "I was reading all these things that came to opposite conclusions. They couldn't all be right." Besides, Hoffman says, "there were studies that didn't represent what I was seeing in clinical practice."

When the NINDS study was published in December 1995, Hoffman paid attention. "It was a big deal," he says. "If tPA worked, it would be a real advance over what we could offer patients during an acute stroke." But, he says, "you [should] never believe one study—especially of a drug that has only a small benefit, and especially a study that is contradicted by other studies, as was the case here." Hoffman is also critical of a study that Genentech says supports the NINDS trial findings. He contends that this study, known as SITS-MOST, shows "how study design and spin can inflate perceived benefit." This is because "no patient with a severe stroke was allowed into SITS-MOST—by design—so the patients who did get included were virtually certain to do well as a group, no matter what treatment they did or didn't get. Comparing them to the much sicker patients in the big trials isn't like comparing apples with oranges—it's comparing apples with elephants."

Hoffman says that the truth in any drug study can be camouflaged by how it is reported. "One way that's been done—for many treatments, and not just [clot-busters]—is to use combination end points." Here's how it works: A single drug can be tested for a variety of outcomes; for example, a cholesterol-lowering drug can be tested for its effect on cholesterol level, blood pressure, and/or rates of heart failure, heart attack, or death. By combining two or more of these outcomes to create a single category, you can say it helped "A and B" even if it only helped A and not B. For example, although there was no statistically significant effect from tPA in the NINDS trial on the number of patients who died, there was a small decrease in disability for those who survived. With the two factors combined, there was technically a decrease in the combination end point of "death and disability." From there, it's a short step to the incorrect assumption that death and disability were *each* decreased—an assumption made by many physicians and patients.

David L. Brown, chief of the division of cardiovascular medicine at the State University of New York, Stony Brook School of Medicine, calls the use of combination end points a "brilliant marketing tool." Brown says that while combination end points have a legitimate purpose when researchers are testing drugs for a rare or infrequent outcome, far too often researchers use the information in ways that "mislead both doctors and the general public."

Another way to make drugs look better and safer than they are is to report or cite only successful studies while ignoring those with bad outcomes. The problem of cherry-picking studies is a very real one, especially for antidepressants, says Erick Turner, a former FDA reviewer, now an assistant professor of psychiatry at the Oregon Health & Science University. Turner recently published research in *NEJM* showing that "when studies of antidepressants were negative, they were reported as negative only 8 percent of the time—but when studies were positive, they were reported as positive 97 percent of the time."

Genentech acknowledges that no controlled study has ever shown—or been conducted to show—that tPA "saves lives" in cases of acute stroke. What the NINDS study showed, Genentech spokesperson Krysta Pellegrino says, is that "patients were at least 30 percent more likely to have a decrease in stroke-related disability three months after treatment compared with placebo." Although Genentech admits that high-risk patients were excluded from analysis in SITS-MOST, Pellegrino says the company believes the data from that study "add to the body of evidence that supports the conclusion that tPA is safe and effective for the treatment of acute stroke."

Ken Johnson, senior vice president of Pharmaceutical Research and Manufacturers of America (PhRMA), says that FDA drug approval procedures are "the gold standard of the world" and that the United States has "one of the strongest drug safety records." He acknowledges, though, that "adverse reactions are sometimes not detected until a medicine has been approved and made available to an entire population," adding, "That's why the postmarket surveillance system is so important." He notes that under the Food and Drug Administration Amendments Act of 2007, the agency has new authority to "require additional postmarket studies and make faster changes to product labeling." The intent is to reduce the time it takes to detect adverse drug reactions and protect the public.

An adverse reaction is exactly what Duane Graveline suspects happened to him. Graveline, a former NASA astronaut and flight surgeon, suffered a bizarre episode in 1999 shortly after he was prescribed the popular statin drug Lipitor for his elevated cholesterol. Just six weeks after he began taking the drug, the normally very active and healthy Graveline plunged down the rabbit hole when he abruptly lost his memory. His wife rushed him to the hospital, where doctors examined him carefully but could find no medical or psychiatric problem. His brain scan showed no sign of a stroke or brain disorder. Then, almost as quickly as his memory had disappeared, it came back after just six hours, without any treatment. Doctors termed the strange episode transient global amnesia, or TGA. The cause? Unknown.

Graveline's case was certainly unusual. Most people with sudden memory loss have suffered a blow to the head, a stroke, or some other medical problem. But Graveline had no history of medical or psychiatric troubles. This made him wonder: Could the episode have been a side effect of Lipitor? Deciding not to test fate, Graveline stopped taking the drug. For the next year he was fine. But when his annual astronaut's physical exam rolled around, he was told that his cholesterol level had crept up again, and his doctor urged him to restart the Lipitor.

while ignoring those with bad results.

Graveline, still uncertain about the connection between the drug and TGA, complied. Within 10 weeks he suffered another, even more severe episode of amnesia. His wife found him wandering outside their home, unable to recognize her and unaware even that he was a physician. That episode also resolved without treatment. "That's when I decided never to take statins again," he said. That's also when Graveline began scouring the medical literature for an explanation of what had happened. What he found troubled him: There were few studies examining statins' side effects on memory, even though cholesterol, he says, plays an important role in brain function. Graveline worried: What if he had had an episode while he was driving? What if a pilot developed TGA during flight?

Graveline's research eventually brought him into contact with Beatrice Golomb, an associate professor of medicine at the University of California, San Diego School of Medicine. Golomb, a dark-haired whiz kid who graduated from the University of Southern California with highest honors at age 19, is an M.D. with a Ph.D. in biology and has been studying cholesterol and statins for more than a decade under research grants given by the Robert Wood Johnson Foundation and the Harry Frank Guggenheim Foundation.

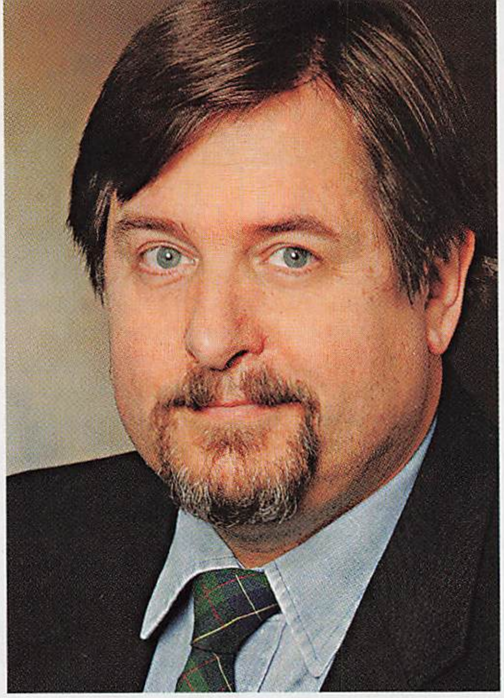
JIM WEHTJE/GETTY IMAGES

Prescription for Change

For years the Food and Drug Administration has failed to adequately monitor the pharmaceutical industry. That conclusion by a special committee at the Institute of Medicine in a September 2006 report titled "The Future of Drug Safety" helped prompt a sweeping reform bill that became law last September. The Food and Drug Administration Amendments Act of 2007 gives the FDA the dollars and legal clout it needs to make a number of important fixes. Its key provisions and other new initiatives include these:

- The FDA will hire 1,300 new employees, with at least 400 dedicated to drug review.
- The agency has earmarked money for the development of a network of organizations to monitor the safety of FDA-approved drugs. Assembled and led by the FDA, the network participants—which include health-care insurers and providers—will have the ability to search millions of their own database records at the agency's request. This surveillance system is built to identify problems, such as side effects of pharmaceuticals and medical therapies, as they emerge.
- All clinical trials of every FDA-approved drug must be registered on an NIH Web site, with results of those trials also posted.
- The FDA can now compel companies to do more studies as warranted even after drugs are approved.
- Penalties of up to $10 million may be imposed for violations of the new REMS (risk evaluation and mitigation strategy) provisions, designed to manage a known or potential serious risk associated with a drug or biological product.
- The agency can now demand more rapid changes to drug warning labels if new side effects emerge.
- Print drug ads now need to have a hotline number consumers can call to report bad reactions. TV commercials must present side-effect warnings in a "clear, conspicuous, and neutral manner"—a mandate the agency is currently defining.

While these are positive steps, it may be years before they are fully implemented, and many people question just how great their impact will be. "Having the authority and using it wisely are two different things," says the chairman of the Cleveland Clinic's department of cardiovascular medicine, Steven Nissen, who advised Congress on the FDA overhaul. "We'll just have to wait and see how well the FDA uses its new powers." **Linda Marsa**



Physician Phil Brewer followed the stroke protocol, then saw his patient die from the drug that was meant to save him.

Golomb says that Graveline's episodes of TGA, and other cases like his, raise questions about the ways statins can affect memory. Her research, she says, shows that although statins can reduce the risk of heart attack, they may also have serious side effects. In Golomb's opinion, the potential benefits of statins may not outweigh their risks except among middle-aged men who have heart disease—or who are at high risk for it. The only way to weigh risks against benefits, she says, is to evaluate all-cause morbidity (sickness) and all-cause mortality (death).

Christopher Loder, a spokesperson for Pfizer, the maker of Lipitor, says that studies of the drug were "not designed nor powered to look specifically at all-cause mortality." The studies, he says, "were powered and designed to look at a composite end point consisting of heart attack or death from coronary causes." In addition, Loder says, "There is overwhelming clinical evidence to support the benefit of Lipitor. All statins have been shown to reduce LDL cholesterol."

Golomb says one reason many doctors overlook risks and believe statins to be safe is that most controlled studies of statins wind up excluding people who originally begin to participate in a study but stop taking the drug because they experience problems from it; these test participants are then dropped from the study as "noncompliant." Confusion arises, Golomb says, "because the absence of evidence that statins cause harm—having excluded those who would have permitted detection of harm—is interpreted wrongly as evidence of absence of harm. And the treatment is generalized to a larger population with a very different risk-to-benefit profile."

John Abramson, a clinical instructor at Harvard Medical School and author of *Overdo$ed America: The Broken Promise of American Medicine,* says he grew concerned when he learned that the authors of professional guidelines recommending an expanded use of statins had ties to the drugs' manufacturers. So, Abramson, a tall, dark-haired man with owlish glasses, decided to review the study data. What he found stunned him. Statins could reduce heart attacks and strokes—but only in a small fraction of the people taking the drugs. "Doctors give statins in one of two ways," Abramson explains. "The first way is to give the drugs to people with elevated cholesterol as primary prevention—to prevent a heart attack, stroke, or other serious cardiovascular event. [These are] people who have never suffered any of those events. The other way to give statins is as secondary prevention, after people have had one of those events or develop diabetes."

Despite broad recommendations in the National Cholesterol Education Program guidelines, Abramson found that there were no studies that showed statins were beneficial for primary prevention for women of any age or men over 65. Yet more than three-quarters of people taking statins take them for primary prevention—meaning that many patients stand to gain no benefit at all. Abramson, who with a colleague published his findings in the British medical journal *The Lancet,* says that even when statins are used for men at the highest risk, "you have to treat about 238 men for one year to prevent one heart attack."

Another problem with statin studies, according to Abramson, is that many do not measure clinically and critically important outcomes like heart attacks, serious adverse events, or all-cause mortality. Instead they measure surrogate markers—outcomes that are associated with a risk of disease—but not a bad outcome itself. In the case of statins, the surrogate marker most commonly used is cholesterol levels. If a drug reduces cholesterol, it is said to be "effective." But lowering cholesterol doesn't necessarily mean a drug will reduce the bad outcomes people are worried about—such as death or heart attack.

"Dying with corrected cholesterol is not a successful outcome," John Abramson says.

This was the issue in last winter's congressional investigation into the nonstatin cholesterol-lowering drug ezetimibe, sold as Zetia and contained in Vytorin. Hearings in January revealed that the release of negative results of a clinical trial of ezetimibe had been delayed. The drug, while lowering cholesterol effectively, failed to slow the progression of carotid artery plaque. While manufacturers Merck and Schering-Plough delayed the negative study's release for more than 18 months, ezetimibe had turned into a blockbuster drug, even though it had never been shown to reduce heart attacks or deaths.

"You can lower cholesterol levels with a drug, yet provide no health benefits whatsoever," Abramson says. "And dying with a corrected cholesterol level is not a successful outcome in my book." Suddenly Abramson, who had taken many hits for his critiques of cholesterol-lowering drugs, was joined by physicians calling for more openness in research and more careful examination of the evidence before drugs are put on the market.

Jerome Hoffman of UCLA agrees, saying it is a shame that in the face of so many medical and pharmacological advances there is such an exposure to risk. "It's ironic that one of the unintended consequences of the publication of so many untenable claims, based on poorly done research and spin, is that it can obscure true advances when they do occur," he says. Citing the number of great successes medical research has brought us—lifesaving drugs from penicillin to insulin, along with invaluable treatments and medical devices—he adds, "It's one more reason why we have to be appropriately skeptical, unafraid to speak out about misleading claims, and insistent upon holding clinical research to the standards of science." ■

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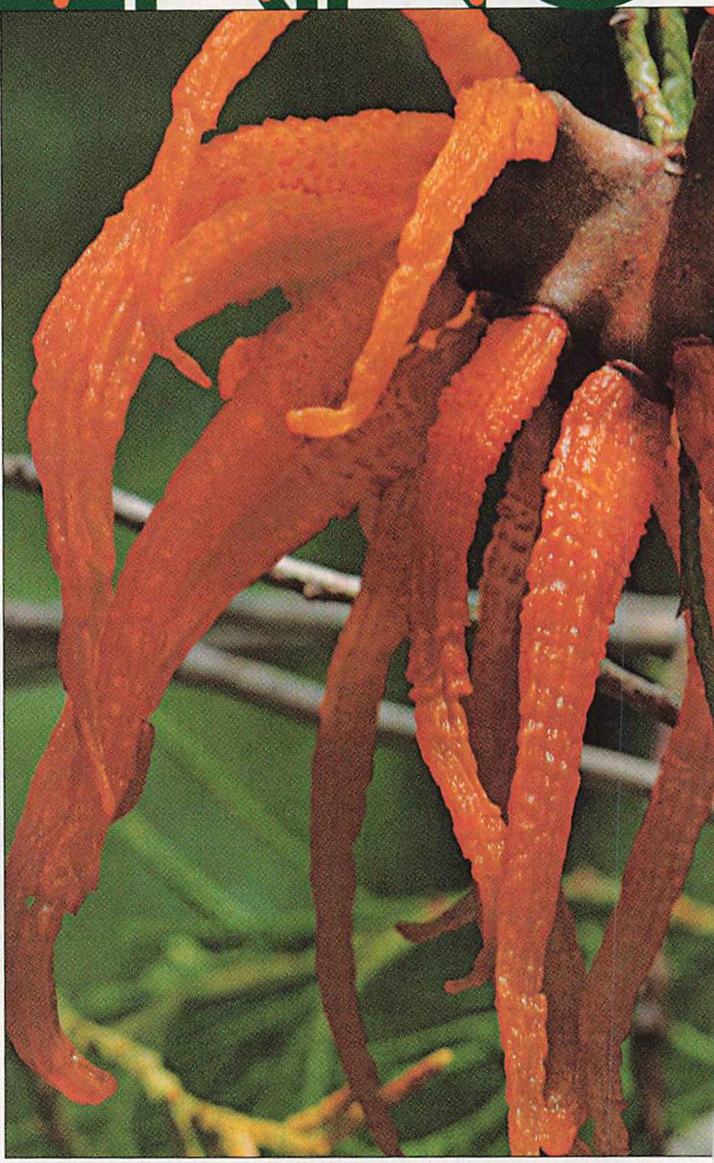


Slimy, repellent, and even deadly, fungi are strange invaders—and, it turns out, our kinfolk.

BY **GORDON GRICE**

The lingering death of a tree in my backyard has me thinking. The Eastern red cedar looked bad—shaggy, wasted, a dandruff of gray decline mixed in with the healthier bluish-green needles. We had seen the cause already, in the form of little spiky galls hanging here and there like drab Christmas ornaments. Each of these ornaments was smaller than a golf ball and seemingly made of wood, which might make you think it was some healthy part of the tree. I picked one off. Each small spike was a spout: a hole surrounded by a sharp woody projection. The ball resisted pressure only as much as a fruit might. Carrying it to the cement walk, I crushed it under my heel. It wasn't difficult. Inside, the thing was pulpy and fibrous, its strands of vegetable matter radiating from a tight core. Its wet texture was like that of the new wood you can find under a tree's bark.

I knew this, from books and such, as cedar-apple rust, a parasite with a provocative life cycle that requires it to jump between juniper and apple hosts. (The Eastern red cedar, despite its name, is actually a juniper.) On the leaves and fruit of apple trees, this parasite manifests itself as leathery spots of discoloration. On junipers it appears as these woody galls. The apple and juniper forms of the parasite are different stages of a single life cycle that involves both sexual and asexual spores.

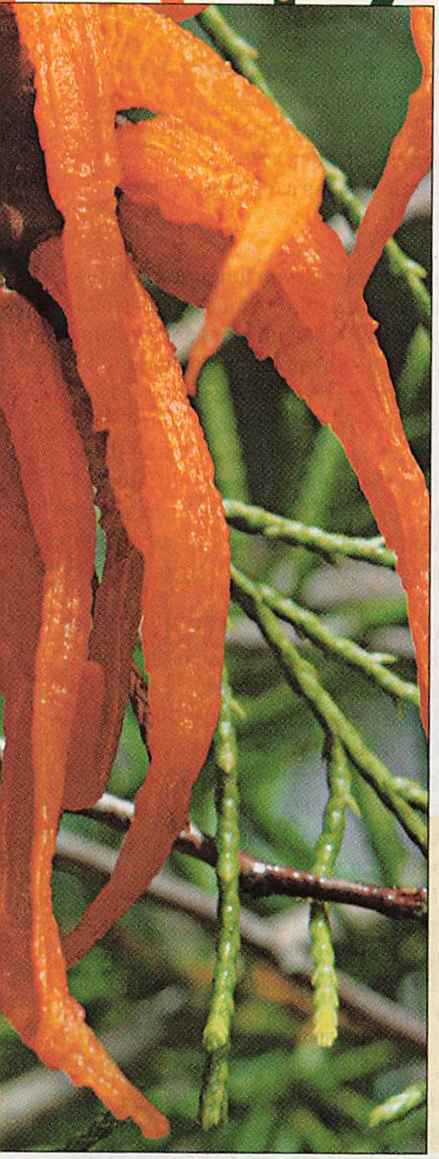
To look at it, though, I wouldn't have recognized this sphere as alien to the tree, made as it was of the tree's own tissues. The tree itself makes the gall, acting on instructions from the fungus, like an animal whose rogue cells produce a tumorous mass.

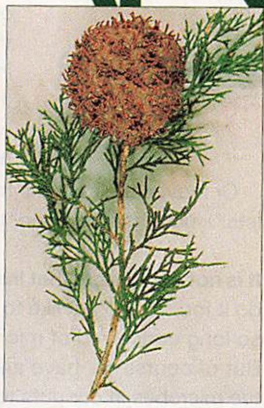
Rain revealed more. It rained for two or three days—a steady, soaking rain that had my sons whooping barefoot on the lawn. They were all excitement. "The parasite opened up!" they told me. Indeed. All over the 50-foot tree, the galls had effloresced. Through each spiky spout a vivid orange tentacle projected. It seemed as if the tree had collided with a swarm of sea anemones. I bent a bough down so the boys could take a closer look. My oldest son poked at one and proclaimed it slimy. I tried its texture myself: wet gummy worms. Our gentlest touches marred them. I almost expected them to recoil.

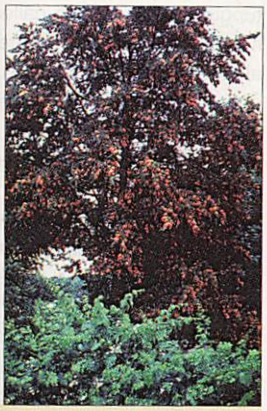
We usually think of fungus as an unhealthy thing, a sign of disease. That is a slander, for parasitism is only one of the possibilities of fungi.

In the woods behind my house I find uncountable lichens. These are, as every high school student learns, symbionts, a fungus paired with an alga or a similar life form. They are the surface I touch when I lay my hand on a fallen tree; they are the first flaky layer my handsaw bites through when I cut dead wood. When my

A PARASITE







An Eastern red cedar infected with cedar-apple rust (far left). The fungus induces galls (top), which in the spring produce wormlike growths (left and above). Spores infect young apple trees, causing lesions on fruits and leaves.

sons climb to prospect for higher views, half their footholds are ledges of lichen or simple fungus.

I call them uncountable. This is only partly because they are numerous. The other reason I can't quantify them is that they lack integrity. The whole leeward side of a box elder tree is crusted with green: Where does one lichen end and another begin?

Fungi are often colonial rather than singular. A million fungal filaments in a patch of soil may be in communication of a sort, all of them sending strands toward a food source when one detects it. There is, of course, no brain, no central command, merely a shared purpose. If we consider one such aggregation an individual, then the largest life forms we know are fungal, stretching for miles within the soil, their total mass rivaling that of the largest animals on earth—blue whales.

If the individuality we tend to think of as fundamental is lacking in the fungi, then so are the species boundaries. Lichens are only one kind of symbiont; the fungi have many. One style, for example, is the mycorrhiza, a combination of fungi with the roots of a plant. The fungi reach where the plant cannot, bringing in minerals and water the plant needs; the plant in turn shares the food it makes from light and water. Though most people are perhaps not familiar with this arrangement, it is the basis of life as we know it. At least 80 percent of plants cohabit in such a manner, and some estimates go as high as 95 percent. The boundaries are not exactly where we are accustomed to draw them because, practically speaking, the average tree or weed or grass is not merely a plant but a combination of plant and fungus.

It is not easy to grasp this or to see it without benefit of excavation, dissection, and microscopy. But the signs are visible, if you look. Sometimes in wet weather I will find an arc of mushrooms in my front yard. It is this distribution that reveals hidden relationships, for the focus of the arc is an oak tree. The mushrooms are the genitals of fungi intimate with the tree. It is possible to trace thicker roots, barely concealed in the dirt, to aggregations of mushrooms.

A moody morning after rain. The rusts poured forth their tentacles again, but after a few hours the tentacles had withered to brown scraps. My oldest son and I decided to retrieve one of them for study. He held a slender branch taut while I cut. The shear blades met in the wet wood with a squeak and a snap; the branch sprang upward, leaving its severed extremity in my son's hands. He plucked the rust off it avidly.

We watered it in a jar and it revived. Overnight, new tendrils of orange slime pushed their way out through the colandered sphere. It did not need rain, then; any drenching would do.

The next stage of our inquiry took place in a white plastic cup. We had learned that the rust spreads orange spores while it is active. Looking over its gelatinous tentacles, I had no doubt our specimen was alive, but we made the experiment anyway. Into the little white cup it went with a fresh supply of water. In the morning, the water showed orange against the cup, spores coloring the water like a weak dose of Tang.

For a few days my sons were always bringing in bigger, juicier specimens of the rust, poking them with sticks, marveling at them. Then their interest dwindled, and I would find week-old jars of the things on shelves and windowsills, tentacles half dissolved in water, retaining only their color.

It used to be said that a fungus was a sort of defective or degenerate plant, one that lacked chlorophyll and so could not make its own food. It was thus reduced to feeding off the work of others—grubbing

Through each spiky spout a vivid orange tentacle projected. I tried its texture: wet gummy worms.

in the soil to devour dead animals, fallen leaves, and damp wood.

Biologists know better now. In the last few years, DNA sequencing has revealed strong evidence for all sorts of things we could hardly have suspected. The method is to look for similar strings of DNA, then to analyze them statistically. It is a probability game. All life on earth comes from a common stock; the more dissimilar two life forms are genetically, the longer it has been since they were one. By applying sophisticated mathematical models, geneticists can estimate how long it takes for certain kinds of differences to arise. Then, by comparing these numbers, they can deduce how closely related different kinds of living things are. For instance, human and chimpanzee diverged much later than human and orangutan. Therefore, we are more closely related to chimps than to orangs.

Much of the genetic data has supported traditional Linnaean taxonomy. For example, the prevailing view has long been that the order containing bats is monophyletic—that is to say, bats are all more closely related to each other than they are to anything else. A minority view held that the two major groups of bats actually had separate origins and that animals such as the squirrellike colugo might be more closely related to one type of bat. But the DNA analysis supports the first view—that all bats belong together in one order, with nothing else included.

Other data have cast the whole Linnaean structure into doubt (which is why there is now a competing branch of systematics, called cladistics, that tries to chart relationships in a much more precise, if cumbersome, way). Some of it is quite counterintuitive. We always knew that whales must have evolved from some sort of land mammal, but who would have suspected they still belong in the order Artiodactyla—the even-toed hoofed animals?

As a result, our vision of life has altered; the kingdoms, the very fundaments of Linnaean biology, have had to be shifted about. The fungi have made up their own kingdom since the late 1800s, but we understand now, better than we used to, at least, what they are. Certain organisms that we called fungi because they were slimy and repulsive and because we didn't know where else to put them—the slime molds, for example—have been exiled from the kingdom. That is not too hard to take, because few of us encounter slime molds with any regularity.

What is harder to take is that these disreputable organisms are our kinfolk. The fungi are not plants at all; they are closer to the animals—to us. We always suspected it, after all. They don't move the way we do, but some of them, the most visible ones, grow so large and are so complex it almost seems a sign of animal life: the mushroom big as a human fist found on your lawn the day after a rain, for example. I have a vivid childhood memory: something smooth and white nesting in the grass, the size and shape of a chicken egg, hard-boiled and peeled. It was not an egg, however; my dog evinced no interest in it. Something about it made me reluctant to touch it. It had no smell, but somehow it reminded me of dog feces, or perhaps merely the Platonic form of disgust. The weird notion that it was an eyeball crossed my mind, and I went so far as to turn it over with a twig, looking for an iris. It was this operation that revealed its true nature, for it tore open under the stick and revealed, first, the stringy origami I associated with the insides of some mushrooms. The other thing this tearing revealed was the smell, which had hitherto been undetectable: the smell of rotten flesh.

Or maybe their overnight appearances simply seem like a sinister kind of magic. Toadstools, elves.

It is not only plants that live in symbiosis with fungi. We animals do it too. We do not like to think about this, because we have for so long conceived of microbes as unclean things, as invaders. But of course we have always been symbionts, dependent on the microbes in our guts to digest our food. We have colonies of fungus inside us. A so-called yeast infection is really an imbalance. It is not a problem that the yeasts are in the human body—they always are. It's a problem that their numbers have, because of some teetering of the pH level, exceeded their usual bounds. It is a natural thing to share our bodies with them, and with all manner of other organisms. As a tree is not simply a tree, we are not simply what we think we are.

Which is not to exonerate them all. Plenty of fungi are pure parasites, and these have invaded almost every form of life. There are specialized fungal parasites of single-celled diatoms and even of other fungi, and some of these cause serious harm. The rust on my red cedar tree was bad for it; it must have been even worse for the apple trees in the neighborhood, for the leaves of the apple are slowly pierced through by the rust, until spore-shooting orange masts sprout from their undersides. The fruit of the apple, too, may be ruined, its hide marred by soft brown patches.

So, too, with the human form. There are fungi to make the feet and the testicles itch, fungi to discolor and deform the fingernails. And there are neighborly fungi content to live within us unobserved, but which will blossom, in the case of a ruined immune system, into devouring sores inside and out. It is a common enough way for people with AIDS to die.

Two years have passed since the last time our red cedar was dazzling in its orange jewelry. The next year we waited in vain for another blooming of that odd fungus life. We had trimmed the galls off where we could reach, hoping to save the tree, but it wasn't our earthbound efforts that drove them away. We could still see dozens of them higher up, dry and drab, refusing to bloom. This is the way of the rust. It dies on apple trees, but on red cedar it can persist, give its life to the wind, or leave its old self to rot.

Our tree grows shaggier, more patched with vanilla and auburn. Within the greenery that remains I can reach dozens of lifeless branches. A good yank is sure to be rewarded with the crack of dead wood. The whole tree is ugly now, truth to tell. It reminds me of nothing so much as the shaggy head of a neglected old man.

Not that I neglect the tree. I prune; I am doing what I can to save its life. ■

CLOCKWISE FROM LEFT: HELEN MCGILL, KIM FLEMING, ARS, TOM VOLK. THIS PAGE: DERRICK DITCHBURN/PHOTO RESEARCHERS

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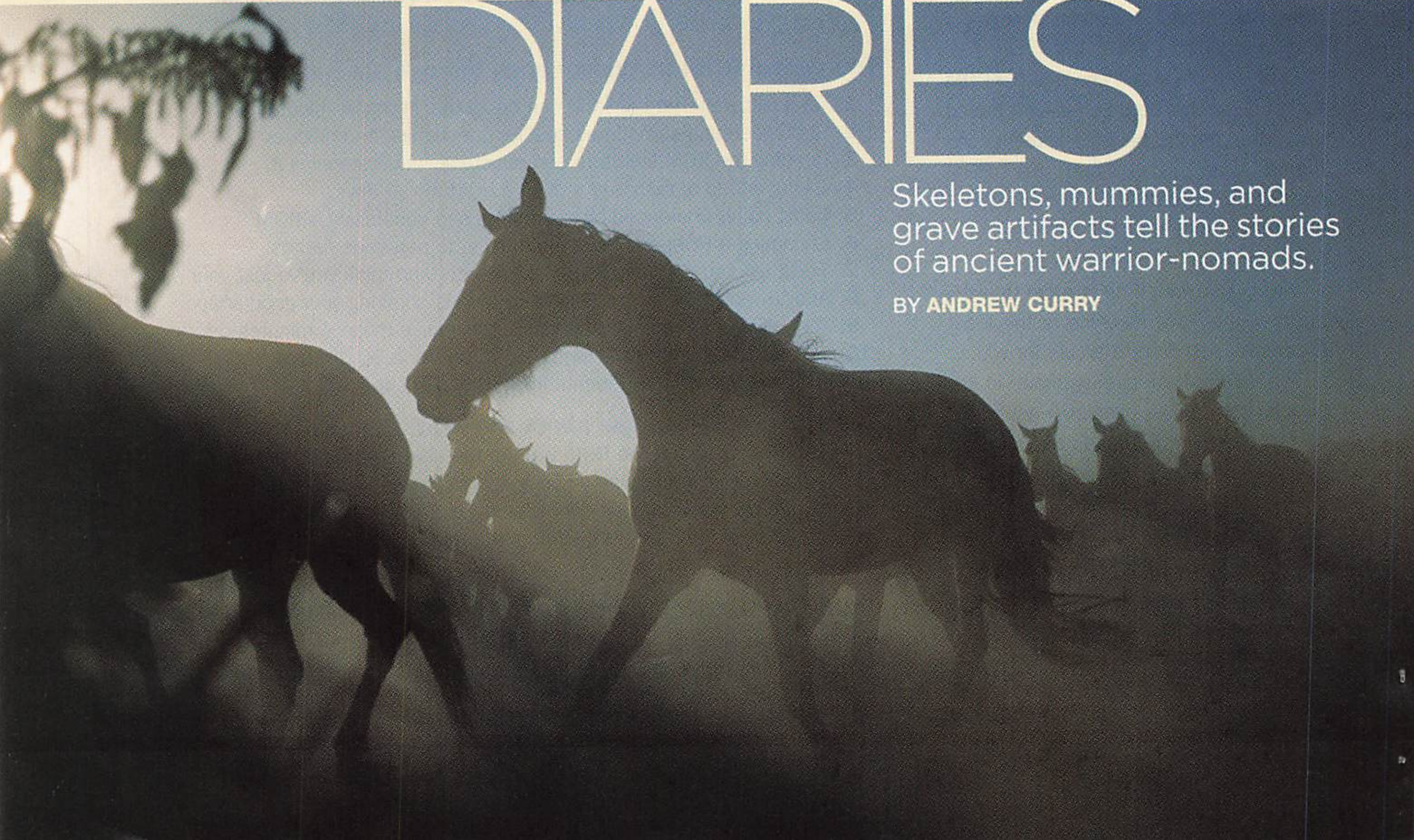
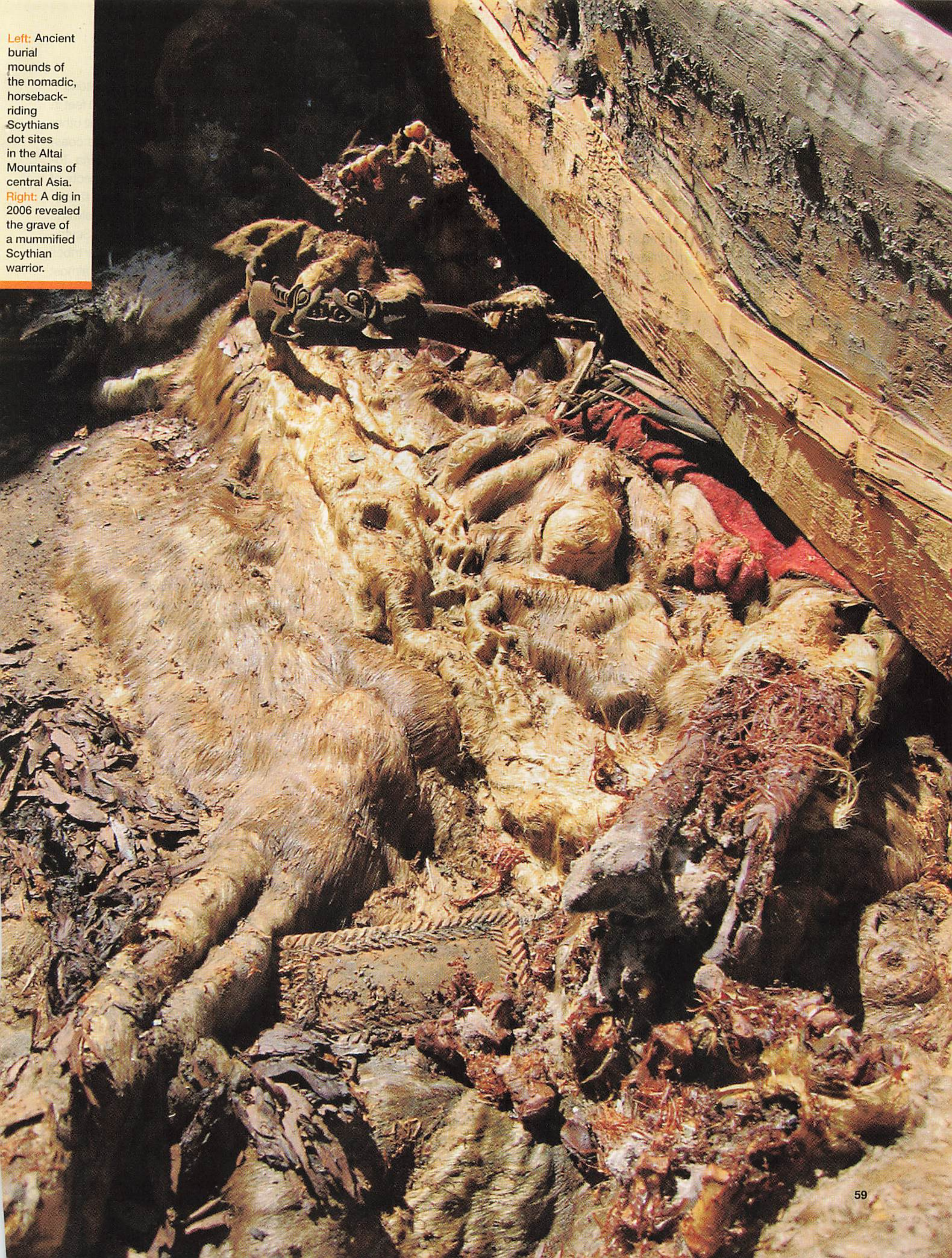


Skeletons, mummies, and grave artifacts tell the stories of ancient warrior-nomads.

BY **ANDREW CURRY**

Left: Ancient burial mounds of the nomadic, horseback-riding Scythians dot sites in the Altai Mountains of central Asia. **Right:** A dig in 2006 revealed the grave of a mummified Scythian warrior.



That the warrior survived the arrow's strike for even a short time was remarkable. The triple-barbed arrowhead, probably launched by an opponent on horseback, shattered bone below his right eye and lodged firmly in his flesh.

The injury wasn't the man's first brush with death. In his youth he had survived a glancing sword blow that fractured the back of his skull. This injury was different. The man was probably begging for death, says Michael Schultz, a paleopathologist at the University of Göttingen. Holding the victim's skull in one hand and a replica of the deadly arrow in the other, Schultz paints a picture of a crude operation that took place on the steppes of Siberia 2,600 years ago.

A carved figurine of a horse decorated the mummy's headdress.

"The man was crying, 'Help me,'" Schultz says. Thin cuts on the bone show how his companions cut away his cheek, then used a small saw to remove pieces of bone, but to no avail. Pointing to a crack in the skull, he describes the next agonizing step: An ancient surgeon smashed into the bone with a chisel in a final, futile effort to free the arrowhead. "Hours or a day later, the man died," Schultz says. "It was torture." The slain warrior's remains were found in 2003, buried with those of 40 others in a massive kurgan, or grave mound, in southern Siberia at a site that archaeologists call Arzhan 2.

To find out more about the lives and deaths of these ancient people, Schultz has spent years teasing out the secrets of their bones, using techniques like those employed at crime scenes. In April he announced the results of his research on the wounded warrior. His body, Schultz says, bore some of the earliest evidence of battlefield surgery. (Prior to this announcement, in October 2007, Schultz had reported a finding on a prince buried at the center of the Arzhan 2 mound. Using a scanning electron microscope, Schultz found signs of prostate cancer in the prince's skeleton. This is the earliest documentation of the disease.)

The Arzhan 2 skeletons, which belong to warrior-nomads the ancient Greeks called Scythians, are part of a spectacular series of finds in remote sites in central Asia. One of the discoveries dates back to the 1940s when mummies were found in the Altai Mountains, which run through Siberia and Mongolia. Later, after the fall of the Soviet Union, when some of the sites became more accessible for excavation, the pace of Scythian-related discoveries picked up. The warrior skeleton Schultz is talking about, for example, was found on a plain not far from the 1940s discovery. More recently, other well-preserved mummies—not skeletons—have been found at altitudes of 8,000 feet in the valleys of the Altai Mountains. Still other discoveries have been made on the coast of the Black Sea and the edge of China. Together, the evidence illuminates aspects of the Scythians' unusual culture, from tattooing warriors to creating intricate metalwork.

Never constituting an empire, the Scythians were a network of culturally similar tribes that ranged from Siberia to Egypt almost 3,000 years ago and faded away around A.D. 100. The Greek historian Herodotus describes the Scythians as murderous nomads. As for how the Scythians—who did not have a written language—perceived themselves, only their artifacts and human remains are left to speak for them.

For Hermann Parzinger, the 49-year-old German archaeologist who excavated the tombs of the wounded warrior and the cancerous prince, the Scythians have been an obsession. Even so, he and his Russian colleague Konstantin Chugonov were surprised to find that the grave mound contained the bodies of 26 men and women, most of them apparently executed to follow the ruler into the afterlife. One woman's skull had been pierced four times with a war pick; another man's skull still had splinters in it from the wooden club used to kill him. The skeletons of 14 horses were arranged in the grave. More impressive was the discovery of 5,600 gold objects, including an intricate necklace weighing three pounds and a cloak studded with 2,500 small gold panthers.

After the Arzhan 2 finds, Parzinger—who until this year headed the German Archaeological Institute—was tantalized by the possibility of finding a well-preserved mummy that would give archaeologists and pathologists insights into the Scythian culture that bare skeletons never could. "High in the mountains, you can find remains in a preserved condition that just doesn't exist in other places," Parzinger, now head of the Prussian Cultural Heritage Foundation in Berlin, says. "Instead of archaeology, it's a kind of ethnography."

In the summer of 2006, his search took him to a windswept plain in the Altai Mountain range that is peppered with Scythian grave mounds. Parzinger worried that mummies in the highlands may not be around much longer, as global warming reverses the chill that has preserved them for millennia. A team of Russian geophysicists had surveyed the area in 2005, using

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The question is: What could create that society? The answer is: Conforming to nature's law of behavior created by whoever or whatever created that law. A law identified by the late Richard W. Wetherill who called it the ***law of absolute right***: ***Right action gets right results; wrong action gets wrong results.*** The law defines right action as logical, rational, and honest; wrong action as illogical, irrational, and dishonest. At present writing, six billion people trying to get their own contradictory ways have unknowingly produced the societal chaos being experienced worldwide.

Conforming to the principles of the behavioral law creates a harmonious society. It is not created by human intelligence. It was not created in thousands of decades by mankind's teachings, religions, or governments. A harmonious society is created by conformance to creation's ***law of absolute right***.

Scientific research and discovery require studying various aspects of nature to learn the principles involved and their functions. For example, researchers have mapped our body's DNA, mapped the earth, space, the tectonic plates, the ocean floor, and surveyed volcanic eruptions.

To acquire knowledge and dispel beliefs, researchers invariably study nature. Whoever or whatever created natural laws also included a behavioral law to establish peaceful, orderly human affairs. Conforming to that law enables people to behave as never before. They will be the survivors who bring to fruition a perfectly performing society!

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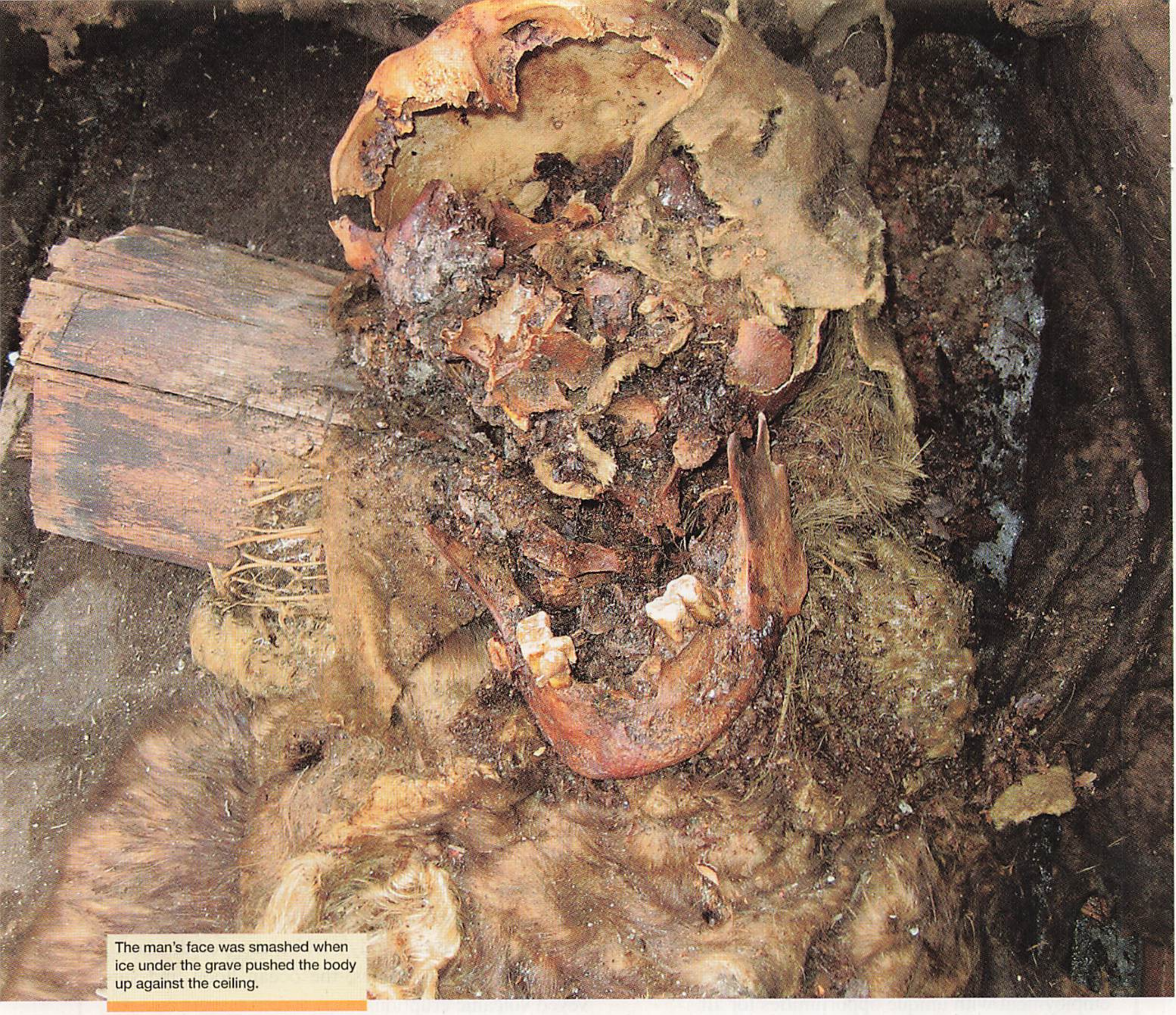

The man's face was smashed when ice under the grave pushed the body up against the ceiling.

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ground-penetrating radar to look for telltale underground ice. Their data suggested that four mounds could contain some sort of frozen tomb.

Parzinger assembled 28 researchers from Mongolia, Germany, and Russia to open the mounds, on the banks of the Olon-Kurin-Gol River in Mongolia. The first two mounds took three weeks to excavate and yielded nothing significant. A third had been cleaned out by grave robbers centuries earlier.

The radar data for the fourth mound—barely a bump on the plain, just a few feet high and 40 feet across—were ambiguous at best. But a thrill went through the team as they dug into it. Buried under four and a half feet of stone and earth was a felt-lined chamber made of larch logs. Inside was a warrior in full regalia, his body partially mummified by the frozen ground.

Researchers recovered the mummy intact, along with his clothes, weapons, tools, and even the meal intended to sustain him in the afterlife. He shared his grave with two horses in full harness, slaughtered and arranged facing northeast. Mongolia's president lent the team his personal helicopter to shuttle the finds to a lab in the country's capital, Ulaanbaatar. The mummy's body spent a year in Germany; his clothes and gear are at a lab in Novosibirsk, Russia.

Before Parzinger opened his grave, the warrior had lain for more than 2,000 years on an ice lens, a sheet of ice created by water seeping through the grave and freezing against the permafrost below. The mummy "had been dehydrated, or desiccated, by the ice in the grave," Schultz says.

Scythian mummies show signs of primitive embalming: Internal organs were removed and replaced with grasses, for instance. The combination of ice and intentional preservation resulted in remarkably resilient specimens. When Schultz shows me the mummy, housed in the same lab as the skeleton of the wounded warrior, the temperature is a comfortable 70 degrees, and sunlight streams onto its leathery flesh.

The mummy's facial features were destroyed. But in this instance—unlike the case of the wounded warrior skeleton—the destruction was inflicted by nature. When the ice lens formed under the burial chamber, it expanded upward. "The extent of the ice was so high, the body was pressed against the logs on the ceiling and smashed," Schultz says. The skull shattered, making

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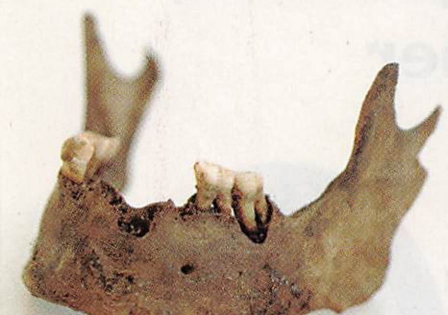

Top: The mummy's jaw shows evidence of advanced gum disease. **Right:** Michael Schultz examines the skeleton at the German Archaeological Institute in Berlin. **Above:** Wolves adorn what was once a gold-plated necklace.

CLOCKWISE FROM LEFT: SISSE BRIMBERG & COTTON COULSON (2); COURTESY GERMAN ARCHAEOLOGICAL INSTITUTE

facial reconstruction impossible. His chest, too, was crushed. Still, a lot can be learned. "You can establish a kind of biography from the body," Schultz says.

He notes that the mummy's teeth are surrounded by pitted bone—evidence of painful gum disease, probably the result of a diet rich in meat and dairy but lacking in fruits and vegetables. Between 60 and 65 years old when he died, the man was slim and just about 5 feet 2 inches. At some point he had broken his left arm, perhaps in a fall. His vertebrae show signs of osteoarthritis from years of pounding in the saddle. Badly worn arm and shoulder joints testify to heavy use. "That kind of osteoarthritis and joint damage is very characteristic if you handle wild horses," Schultz says.

The clues reinforce what Parzinger and others have suspected: He belonged to the Scythians, a seminomadic culture that once dominated the steppes of Siberia, central Asia, and eastern Europe. Beginning around 800 B.C., the Scythians thundered across the central Asian steppes, and within a few generations, their art and culture had spread far beyond the steppes of central Asia.

The Scythians' exploits struck fear into the hearts of the ancient Greeks and Persians. Herodotus wrote about their violent burial customs, including human sacrifice (which the Arzhan 2 find tends to confirm) and drug-fueled rituals. He speculated that they came from mountains far to the east, in the "land of the gold-guarding griffins."

Archaeologists say the Scythians' Bronze Age ancestors were livestock breeders living in the highlands where modern-day Russia, Mongolia, China, and Kazakhstan intersect. Then "something changed," Parzinger says. Beginning around 1000 B.C., a wetter climate may have created grassy steppes that could support huge herds of horses, sheep, and goats. People took to horseback to follow the roaming herds. Around 800 B.C., all traces of settlements vanish from the archaeological record.

Archaeologists usually draw their clues from ordinary artifacts and human remains, so while the grave gold from the nomadic Scythians is sumptuous, the real prize is the ancient people themselves. A century of digging at lower altitudes and in the warm Ukrainian plains rarely yielded more than skeletons or jewelry.

In the late 1940s, Soviet archaeologist Sergei Rudenko traveled to the Pazyryk region of the Altai Mountains and made some stunning finds. Richly appointed wooden chambers contained well-preserved mummies, their skin covered in elaborate, twisting animal tattoos. Their brains, intestines, and other organs had been removed and the corpses sewn up with horsehair. The dead had been dressed, armed, and laid to rest in chambers lined with felt blankets, wool carpets, and slaughtered horses.

In 1992 Russian archaeologists began a new search for ice lenses—and mummies. Natalya Polosmak, an archaeologist in Novosibirsk, discovered the coffin of an elabo-

rately tattooed "ice princess" with clothes of Chinese silk at Ak-Alakha, another site in the Altai Mountains. Other finds in this area included a burial chamber with two coffins. One coffin contained a man, the other a woman armed with a dagger, war pick, bow, and arrow-filled quiver. She wore trousers instead of a skirt. The find lent credence to some scholars' suggestions of a link between the Scythians and the legendary Amazons.

In the early 1990s, just a few miles from that site, Parzinger's partner Vyacheslav Molodin uncovered the more modest mummy of a young, blond warrior. The burial style resembled that of Parzinger's mummy, the one found at the Olon-Kurin-Gol River whose face was crushed by ice.

Parzinger fears global warming may soon put an end to the search for Scythians. Rudenko's dig diaries contain reports of weather far colder than what modern archaeologists experience in the Altai. "When you read descriptions from the 1940s and compare them with the climate of today, you don't need to be a scientist to see there's been a change," Parzinger says.

Geographer Frank Lehmkuhl from the University of Aachen in Germany has been studying lake levels in the Altai region for a decade. "According to our research, the glaciers are retreating and the lake levels are rising," Lehmkuhl says. With no increase in the region's rainfall, the change "can only come from melting permafrost and glaciers."

As the permafrost thaws, the ice that has preserved the Scythian mummies for so many centuries will thaw too. In the Olon-Kurin-Gol grave, the ice that once crushed the mummy against the roof of the burial chamber had receded nine inches by the time the chamber was opened. Within a few decades, the ice lenses may be completely gone. "Right now we're facing a rescue archaeology situation," Parzinger says. "It's hard to say how much longer these graves will be there." ■

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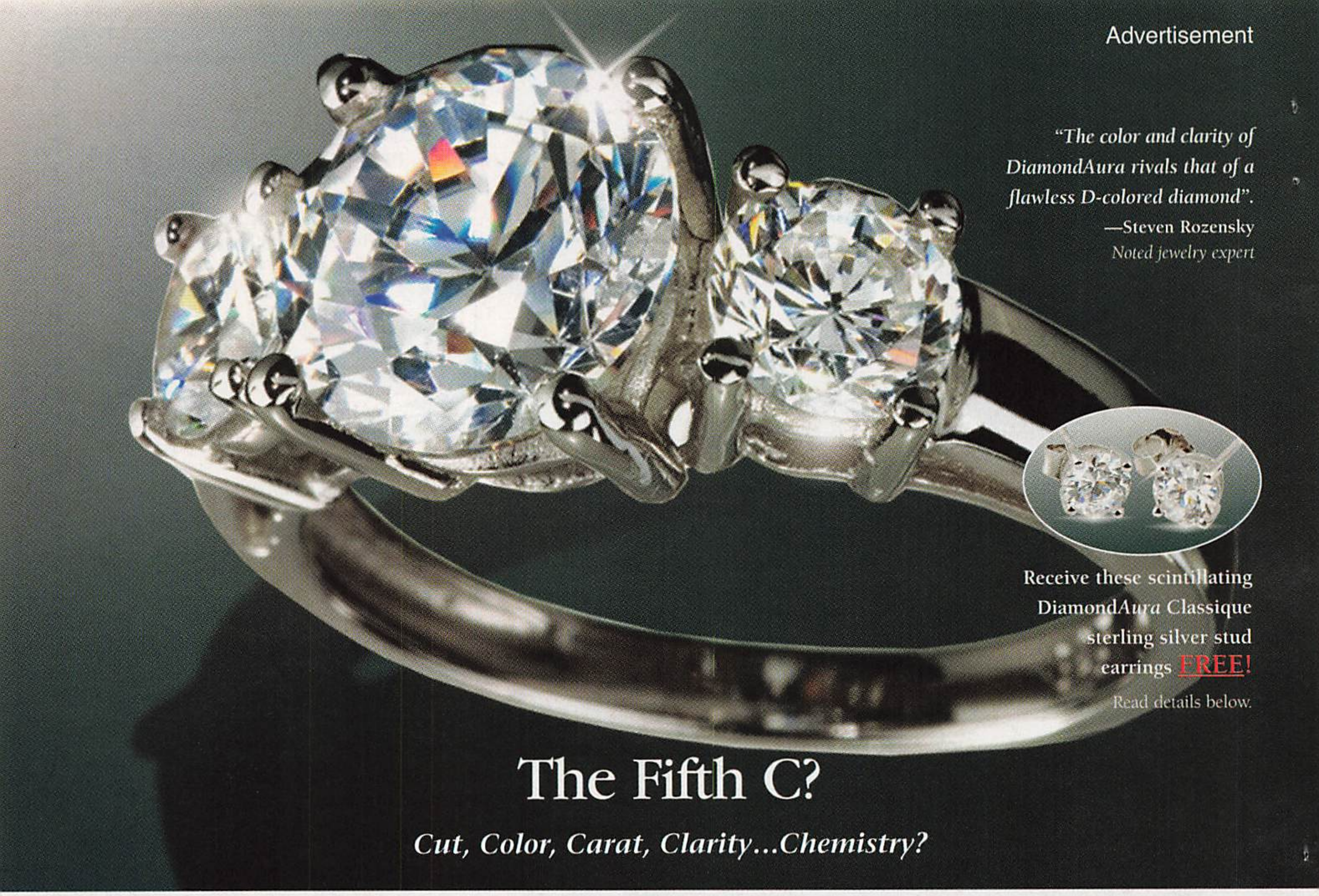

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Clarity	"IF"	**"F" Faultless**
Dispersion/Fire	0.044	**0.066**
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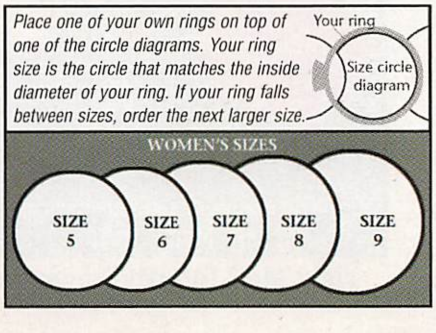
Place one of your own rings on top of one of the circle diagrams. Your ring size is the circle that matches the inside diameter of your ring. If your ring falls between sizes, order the next larger size.



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WHY LAUGHING MATTERS

Numbers and laughter will last a million years. BY **JIM HOLT**

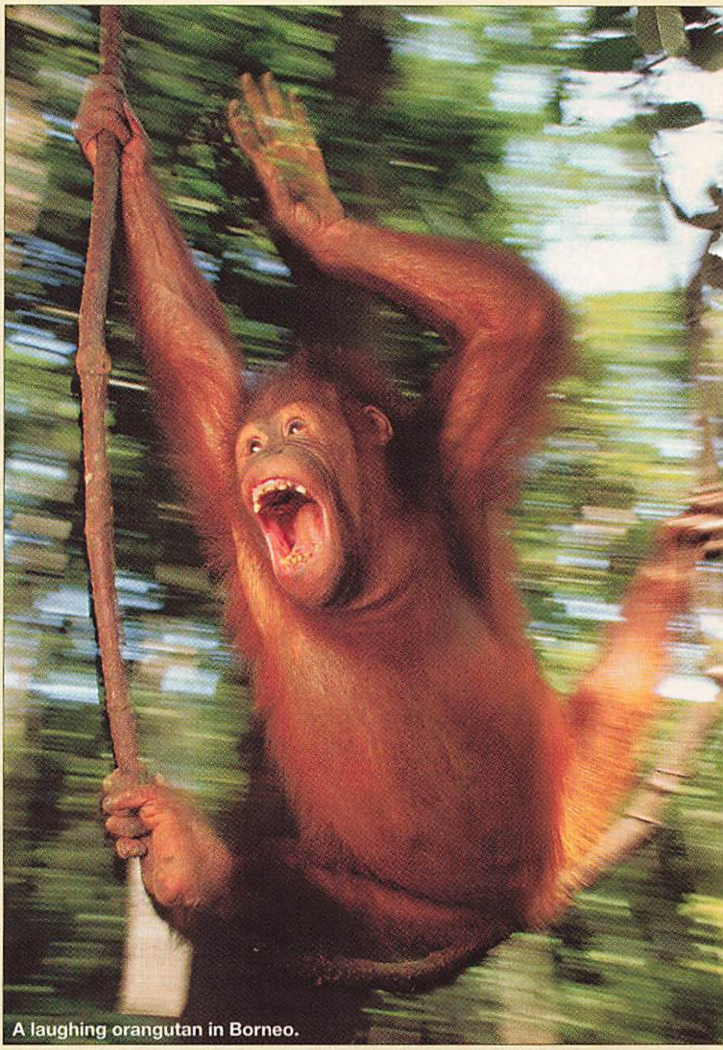
Futurologists envision a world a million years from now in which the entire solar system has been turned into computronium and nanobots transform our garbage into foie gras. But in my experience, the repeated sin of futurologists is that they often extrapolate from what is new rather than from what is old. Computers and nanotechnology, impressive though they are, are things of relatively recent origin. As such, they are unlikely to be around for very long.

To find something that will pretty certainly endure into the distant future, we are obliged, paradoxically enough, to go back much farther into the past. And if we could cast a look back several million years, we would see, among other things, laughter and numbers. So we can be pretty confident that laughter and numbers will survive long after most of what we're familiar with is gone.

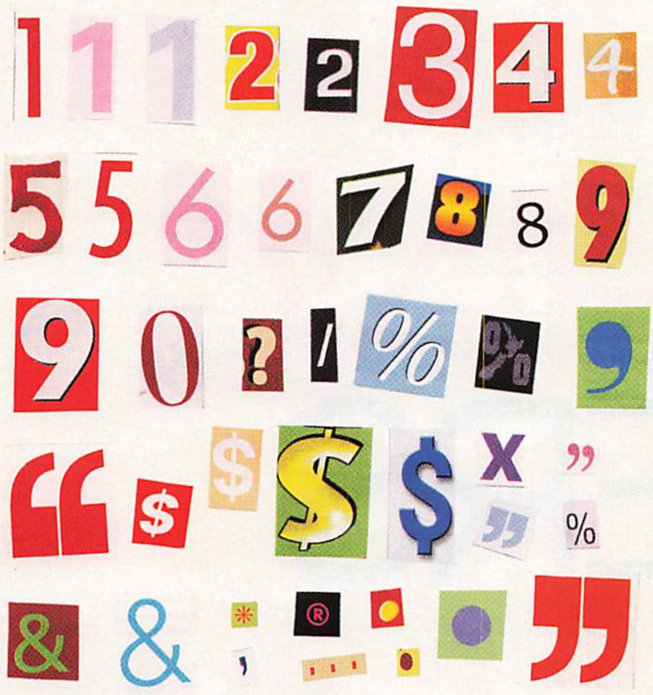
The insight that old things tend to last and new things tend to disappear flows from the Copernican principle. This principle says, in essence, "You're not special." Before Copernicus, we imagined that we occupied a very special place at the center of the universe. Now we know better: We are on an average planet in an average galaxy in an average cluster. But the Copernican principle applies to time as well as to space. If there is nothing special about our perspective, we are unlikely to be observing any given thing at the very beginning or the very end of its existence. And that rather obvious point can lead to some interesting predictions.

Consider the longevity of the human race. If there is nothing special about the moment at which we observe our species, then it is 95 percent certain that we are seeing *Homo sapiens* in the middle 95 percent of its existence—not the first fortieth (2½ percent) or the last fortieth (2½ percent). Humans have already been around for about 200,000 years. That means we can, with 95 percent confidence, expect the species to endure for at least another 5,100 years (1/39 x 200,000) but for no more than 7.8 million years (39 x 200,000).

It was Richard Gott III, an astrophysicist at Princeton University, who pioneered this sort of reasoning. In a paper published in *Nature* on May 27, 1993, "Implications of the Copernican Principle for Our Future Prospects," Gott noted that the Copernican-based calculation gives *H. sapiens* an expected total longevity comparable to that of other hominid species



A laughing orangutan in Borneo.



(*H. erectus* lasted 1.6 million years) and of mammal species in general (whose average span is 2 million years). It also gives us a decent shot at being around a million years from now.

What else might be around in the Year Million? Consider something of recent origin, like the Internet. The Internet has existed for about 25 years now (as I learned by going on the Internet and looking at Wikipedia). By Copernican reasoning, this means we can be 95 percent certain that it will continue to be around for another seven-plus months but that it will disappear within 975 years. So in the Year Million, there will almost certainly be nothing recognizable as the Internet. (This is, perhaps, not a terribly surprising conclusion.) Ditto for baseball. Ditto for what we call industrial technology, which, having come into existence a little more than two centuries ago, is likely to be superseded by something strange and new in the next 10,000 years.

Laughter and numbers, on the other hand, are good bets to survive a million years because they are two of the oldest things that are part of our lives today. How do we know this? Because we share both laughter and a sense of number with other species, and therefore with common ancestors that existed millions of years ago.

Take laughter. Chimpanzees laugh. Charles Darwin, in *The Expression of the Emotions in Man and Animals,* noted that "if a young chimpanzee be tickled—the armpits are particularly sensitive to tickling, as in the case of our children—a more decided chuckling or laughing sound is uttered; though the laughter is sometimes noiseless." Actually, what primatologists call chimp laughter is more like a breathy pant. It is evoked not only by tickling but also by rough-and-tumble play, games of chasing, and mock attacks—just as with children prior to the emergence of verbal joking at age 5 or 6.

The human and chimpanzee lineages split off from each other between 5 million and 7 million years ago. On the reasonable assumption that chimp and human laughter are homologous rather than independently evolved traits, laughter must be at least 5 million to 7 million years old. (It is probably much older; orangutans also laugh, and their lineage diverged from ours about 14 million years ago.) So, by the Copernican principle, laughter is quite likely to be around in the Year Million.

Now take numbers. Chimps can do elementary arithmetic, and they have even been trained to use symbols like numerals to reason about quantity. But the sense of number is not confined to primates. Animals as diverse as salamanders, pigeons, raccoons, dolphins, and parrots have the ability to perceive and represent numbers. A few years ago, researchers at MIT discovered that macaque monkeys had specialized "number neurons" in the brain region that corresponds to the human number module. Evidently the number sense has an even longer evolutionary history than laughter. So again, by the Copernican principle, we can be quite certain that numbers will be around in the Year Million.

Chimps can do elementary arithmetic, and salamanders, pigeons, raccoons, and dolphins perceive numbers.

But what will our descendants' mathematics look like? And what will make them laugh? The first question might seem the easier to answer. Mathematics, after all, is supposed to be the most universal aspect of human civilization, the part we assume would extend even to intelligent life elsewhere in the cosmos. In Carl Sagan's science fiction novel *Contact,* aliens in the vicinity of the star Vega beam a series of prime numbers toward Earth. The book's heroine, who works for SETI (Search for Extraterrestrial Intelligence), realizes with a frisson that the prime-number pulses her radio telescope is picking up must be generated by some form of intelligent life. But if the aliens beamed their jokes at us instead, we probably wouldn't be able to distinguish them from the background noise. Indeed, sometimes we can barely distinguish the jokes in a Shakespeare play from the background noise. Just as nothing is more timeless than number, nothing is more parochial and ephemeral than humor, the core of laughter—or so we imagine. We are confident that a civilization a million years more advanced than our own would find our concept of number intelligible (and we, theirs), but our jokes would have them scratching their heads in puzzlement.

That is how we see matters at the moment. In the Year Million, though, I think the perspective will be precisely the reverse. Humor will be esteemed as the most universal aspect of culture. And number will have lost its transcendental reputation and be looked upon as a local artifact, like a computer operating system or an accounting scheme. If I am right, then SETI scientists should not be listening for primes but for something quite different.

Prime numbers—the numbers that can't be split up into smaller factors and are thus the atoms of arithmetic—have an almost holy status today. What makes them seem transhuman to us now is their sheer orneriness. There are infinitely many of them, and they seem to crop up almost at random among the rest of the numbers. "There is no apparent reason why one number is prime and another not," the mathematician Don Zagier declared in his inaugural lecture

PREVIOUS PAGE: FRANS LANTING/MINDEN PICTURES. THIS PAGE: JOANNE HARRIS & DANIEL BUBNICH/SHUTTERSTOCK

at Bonn University in 1975. "To the contrary, upon looking at these numbers, one has the feeling of being in the presence of one of the inexplicable secrets of creation."

But the prime numbers are not really as transcendental as all that. They do obey a law. We just don't grasp the law—yet. In 1859 the German mathematician Bernhard Riemann put forward what is now almost universally regarded as the greatest unsolved problem in mathematics: the Riemann hypothesis. This hypothesis holds the key to the primes' true pattern, and once its truth or falsity is resolved, prime numbers will be rendered transparent to our understanding. How long must we wait? Mathematicians great and not so great have been trying to crack this nut ever since Riemann put it out there. "It will be another million years at least," the late number theorist Paul Erdös pronounced, "before we understand the primes."

The Copernican principle yields a rather different estimate. The Riemann conjecture has been open since it was first posed 149 years ago. That means we can be 95 percent certain that it will survive as an open problem for at least another four years or so (1/39 x 149) but that it will be dispatched within the next six millennia (39 x 149), well short of the Year Million. When it is solved, the prime numbers will finally be stripped of their cosmic otherness. We will realize that, like the rest of mathematics, they are man-made, a terrestrial artifact. They will seem about as trivial as a game of tic-tac-toe.

And how about laughter? Perhaps the best way to gauge future humor is to look at other primates: What do chimps find funny? The Central Washington University researcher Roger Fouts reported that Washoe, a chimpanzee who was taught sign language, once urinated on him while riding on his shoulders. The chimp snorted and made the sign for "funny." Washoe was also observed playfully wielding a toothbrush as if it were a hairbrush. Moja, another of Fouts's signing chimps, called a purse a "shoe" and wore it on her foot. A signing gorilla trained by another researcher appeared to derive amusement from offering rocks to people as "food." Such supposed instances of simian humor (similar to the jokes of preschool children) involve the deliberate misnaming or misuse of things. They thus fit nicely under one of the three classic theories of humor, the incongruity theory, which holds that mirth results when two things normally kept in separate compartments of the mind are abruptly and surprisingly yanked together.

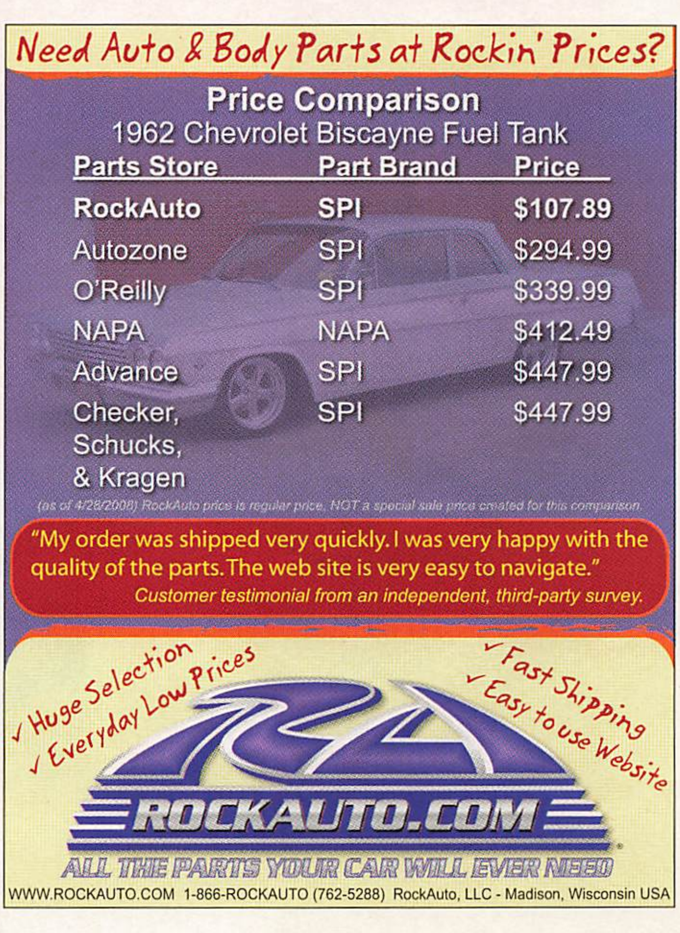
But why should the perception of incongruity cause a spasm of noisy chest-heaving? Laughter has long been viewed as a so-called luxury reflex, one that serves no obvious evolutionary purpose. In recent years, though, practitioners of the art of evolutionary psychology have been more imaginative in coming up with Darwinian rationales. One of the more seductive comes from the neuroscientist V. S. Ramachandran of the University of California at San Diego, who has advanced what might be called the false-alarm theory of laughter. A seemingly threatening situation presents itself; you go into fight-or-flight mode; the threat proves spurious; you alert your (genetically close-knit) social group to the absence of actual danger by emitting a stereotyped vocalization—one that is amplified as it passes contagiously from member to member.

Once the mechanism of laughter was set in place by evolution, the theory goes, it could be hijacked for other purposes: the expression of contempt for out-groups (as the superiority theory of humor claims) or the ventilation of forbidden sexual impulses (the relief theory of humor). But at the core of the original false-alarm mechanism of laughter is incongruity: the incongruity of a grave threat revealing itself to be trivial—or, as the philosopher Immanuel Kant (an advocate of the incongruity theory) put it, "the sudden transformation of a strained expectation into nothing." Incongruity is arguably the primeval kernel of laughter. And therefore, by the Copernican principle, it is likely to be the kernel of laughter in the Year Million.

That is why I think humor and mathematics will ultimately switch places, so to speak. The transcendence that numbers seem to possess arises from mere kinks in our local understanding, kinks that will eventually get straightened out. But the essence of humor is the dialectic between something and nothing, the most universal categories of all.

And what will jokes look like in the Year Million? We will laugh when incongruity is resolved in a clever way, when a strange-seeming something is exposed as a trivial nothing—when a proof of the Riemann hypothesis dissolves the Platonic otherness of the primes into obvious tautology, and what is today regarded as the hardest problem ever conceived by the human mind becomes a somewhat broad joke, fit for schoolchildren. We might laugh even harder at the thought that the end of the universe—its disappearance in a Big Crunch or expansion into dilute nothingness—itself has the logical form of a joke. ■

Adapted from Jim Holt's essay, "The Laughter of Copernicus," in *Year Million: Science at the Far Edge of Knowledge,* edited by Damien Broderick (Atlas and Company, $16). Holt is also the author of *Stop Me If You've Heard This: A History and Philosophy of Jokes* (W. W. Norton and Company).



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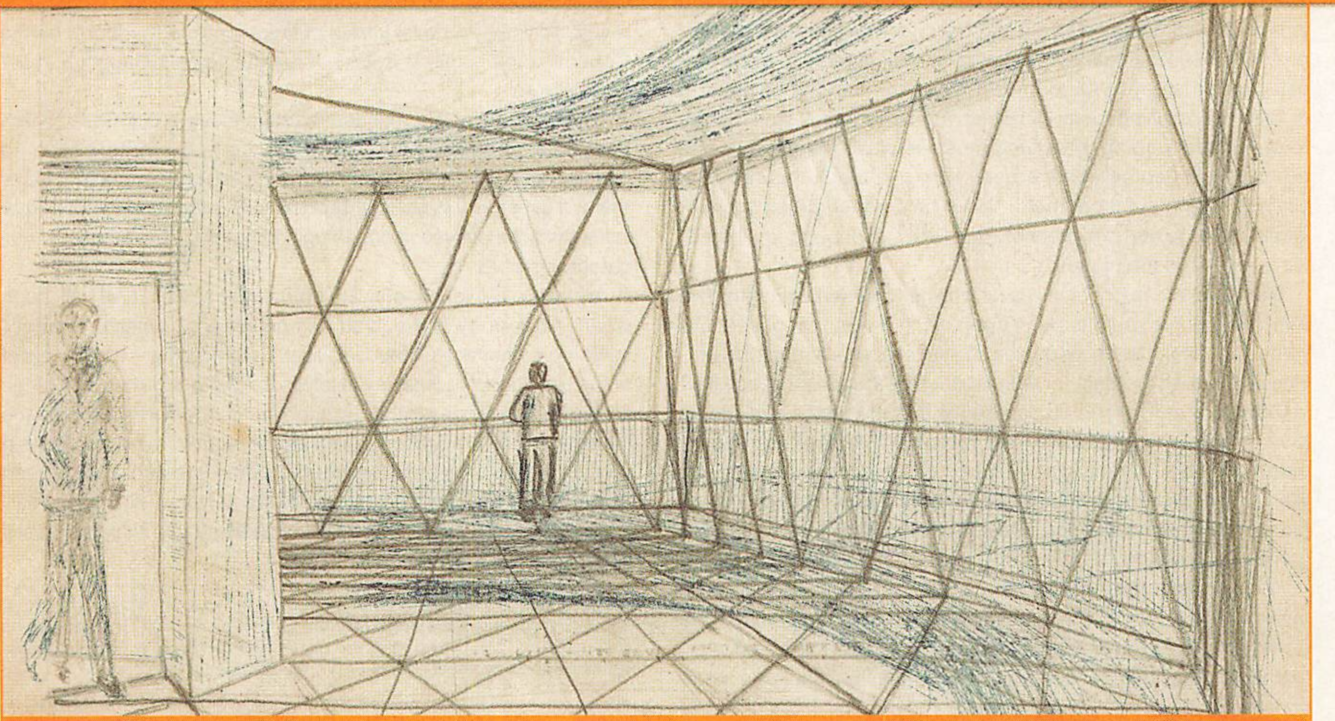
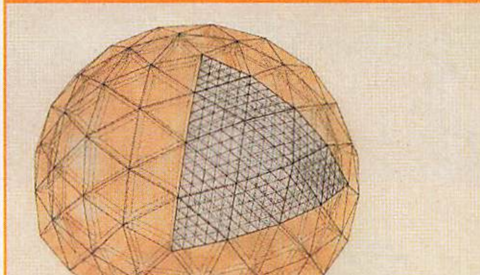


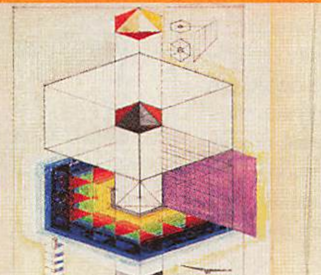
DO MORE WITH LESS

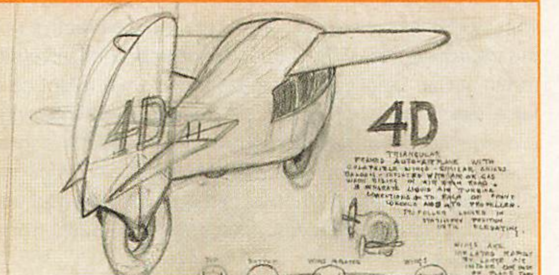
Above and below: Buckminster Fuller's original sketches of a house, a dome, an apartment tower, and an airplane with inflatable wings.

Although the interlocking tetrahedrons of the geodesic dome have yet to replace the inefficient rectangles of modern housing, Buckminster Fuller's legendary building design remains the best combination of strength and lightness ever devised. The dome's structure inspired an explanation of the architecture of human red blood cells, the discovery of fullerene molecules (which take the form of buckyballs and carbon nanotubes), and ways to process data for robotic vision.

Fuller imagined a full-scale technological revolution in which designers would run the world, and innovation and conservation would benefit everyone, even the have-nots. His notebooks, models, and inventions—including the last surviving three-wheeled Dymaxion car—are now on display at the Whitney Museum of American Art in New York City. The exhibition "Buckminster Fuller: Starting With the Universe" runs from June 26 through September 21; it will travel to Chicago in the summer of 2009. **Amber Fields**







COURTESY R. BUCKMINSTER FULLER ESTATE

MY DOG IS SMARTER THAN YOUR DOG

In April, Brazilian scientists announced that they had taught a dog named Sofia to use a computer keyboard. The world's first canine typist can press paw-size keys to ask for water or to be petted. Dogs seem more human the more we learn about them—but at least we've still got them beat on IQ. Or have we?

The Pooch IQ Kit is a $49.99 home "IQ test" containing a sackful of soft, squeaky rubber and plastic toys and a 49-page instruction booklet. Tests include a dog's version of object permanence (if a cup is placed over a treat, is the treat still there?), response to an unfamiliar scene (why is my owner wearing a black ski mask and staring at me?), operant conditioning (turning in circles over and over again is a good way to get a pat on the head), and problem solving (how can I get my mouth on that Milk-Bone?).

When I pulled out the test, my puppy, Finnegan, sniffed the sack of toys with great interest. This gained him no points. Then we began the exam. Finding a treat under a cup? No problem—though I have to think his sense of smell helped him more than his reasoning skill. Pulling squeaky toys out of a container? Right up his alley, as befits a mixed-breed hunting dog. He scored off the charts on a test requiring him to pull treats out of a rubber cone. And he began eating the cone, to boot.

Then the instructions told me to squeak a toy while keeping it out of view. Finnegan loves squeaking things. He sat and gazed pleadingly at me, the very model of canine self-restraint.

He lost points.

For another challenge, I followed the instructions to place a treat under a plastic igloo and weigh it down with books. The igloo opening is too small for a snout. Finnegan set to it, pawed the books, then looked at me. He lost points again. Why?

Like other "intelligence tests" before it, this pooch IQ test rewards enthusiastic, curious dogs and penalizes those who turn to humans to solve their problems. This follows a long-held tenet of dog training that smart dogs take action while dumb dogs sit and stare. But I believe that the wide-eyed, constant canine gaze toward your face is actually a whole different kind of clever.

Comparative psychology research in the last decade has shown that dogs excel at social cognition, out-testing even some primates. Dogs follow our gaze, our pointing fingers, and our turning heads. They know that our attention is more distracted when we're on the phone than when we're sitting reading a book, and that by barking or putting their heads in our laps, they can get our attention when they need it.

The truth is, I am often better equipped to solve the problem of the hidden treat than Finnegan is. So it's a better option to give up and turn to me—perhaps the smartest strategy of all. **Alexandra Horowitz**

Alexandra Horowitz is writing a book on the mind of a dog.

TOP: IMAGE SOURCE/DIGITAL RAILROAD. BOTTOM: DREAMSTIME/BRIGHTQUBE

BOOKS

The Science of Fear: Why We Fear the Things We Shouldn't—and Put Ourselves in Greater Danger

by Daniel Gardner
(Dutton, $24.95)

In the aftermath of 9/11, many Americans were so afraid of flying that they chose to drive instead. That decision, based on the perceived threat of another airliner hijacking, led to 1,600 casualties in the following year. The families of the people who died in those crashes thought they had lost them to "the routine traffic accidents we accept as the regrettable cost of living in the modern world." Daniel Gardner begs to differ: What killed them was fear.

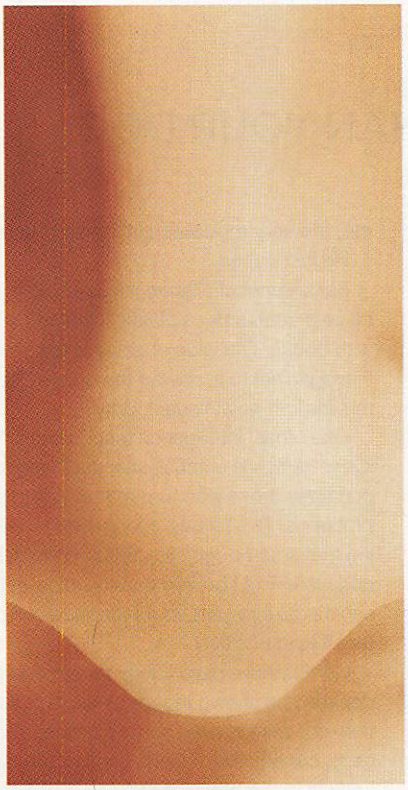
How do we decide what to dread, and why do we do it so badly? Threats such as asteroid impacts, online pedophiles, and terrorist attacks trigger gut reactions so powerful that they override rational thought, Gardner explains, and pretty soon we are willing to carry gas masks to protect ourselves from a chemical weapons attack—but not to exercise and eat our fruits and veggies. When you weigh the risk of death by terrorist attack (less than 1 in 10,000) against that from heart disease or cancer (nearly 1 in 3), it makes much more sense to forgo the drama and join a gym.

Gardner achieves some very clearheaded calm-mongering. By showing us how we misunderstand and miscalculate risks, he gives us the tools to rethink them. *The Science of Fear* shows that our Stone Age reflexes don't have to rule. **Jane Bosveld**

STRAIGHT FROM THE PAGE

> “The proponents of Intelligent Design seek nothing less than a true scientific revolution, an uprising of the first order that would do a great deal more than just displace Darwin from our textbooks and curricula. They seek the undoing of four centuries of Western science, and that surely should be enough to make anyone sit up and pay attention.”

Reprinted from *Only a Theory: Evolution and the Battle for America's Soul* by Kenneth R. Miller, © 2008. With permission of the publisher, Viking.



What the Nose Knows: The Science of Scent in Everyday Life

by Avery Gilbert
(Crown, $23.95)

“Strictly speaking, smells exist only in our heads,” writes psychologist and smell expert Avery Gilbert. “Molecules exist in the air, but we can only register some of them as ‘smells.’” It is impossible even to count how many scents there are. Yet the same chemicals turn up over and over again: The molecule MMP is the key aroma in green tea, grapefruit, basil, and cabernet sauvignon wine; dimethyl sulfide shows up in oysters, tomato paste, “spoiled refrigerated chicken, and pinto-bean farts.”

Gilbert covers areas from scent branding—even Samsung's flagship store has a signature perfume—to how to sniff. And he offers an explanation for why Freud dismissed smell as an unimportant, vestigial sense. “The repeated insults of cocaine, nose surgery, influenza, sinus infection, cigar smoking, and finally aging left him with a clinically impaired sense of smell,” Gilbert writes. At least Freud didn't have cacosmia, a medical condition that can make everything smell like, well, feces. **Jane Bosveld**

ON THE NIGHTSTAND

MAX TEGMARK

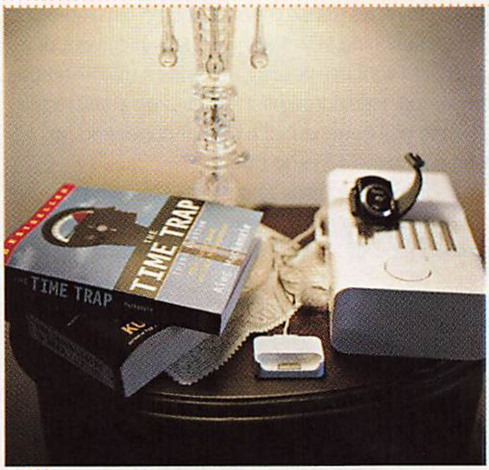
What do your private spaces say about you? University of Texas at Austin psychologist Sam Gosling wants to put a guest book in his medicine cabinet to surprise snoopers—but he won't hold their nosiness against them. Gosling, author of the new book Snoop: What Your Stuff Says About You *(Basic Books, $25), has spent the past 10 years developing a science of predictive snooping. He can tell whom you vote for (it's in the sports decor, not the art supplies); he knows if you are actually tidy or just shove things into drawers right before a guest arrives.*

We sent Gosling photographs of MIT cosmologist Max Tegmark's bedroom and nightstand (see DISCOVER *Interview, page 38) without telling him whose it was.*

So, Dr. Gosling, what do you see?
This looks like a creative person—imaginative, unusual, somebody who might be pushing the boundaries. He values the past but not at the expense of being forward-thinking and modern and hip. I'm like 95 percent sure it's a guy. Is that true?

Yes. How can you tell all this?
The type of decor and the sophisticated sense of aesthetics tell me that this person is probably quite high on the trait of openness to experiences. That's one of the easiest things to pick up in most people's spaces normally. The style is rooted in history, but that book—and the iPod dock and the clock and the watch—are sort of modern. It's a clean, sparse room, which indicates high conscientiousness—somebody who gets things done, thinks ahead, is focused. But he is a bit impulsive: The books are kind of plunked down, not put there carefully; the cloth that the lamp is sitting on is a little bit ruffled.

If he's a scientist, what kind of theories does he come up with?
Visionary, I would say. Unconventional.



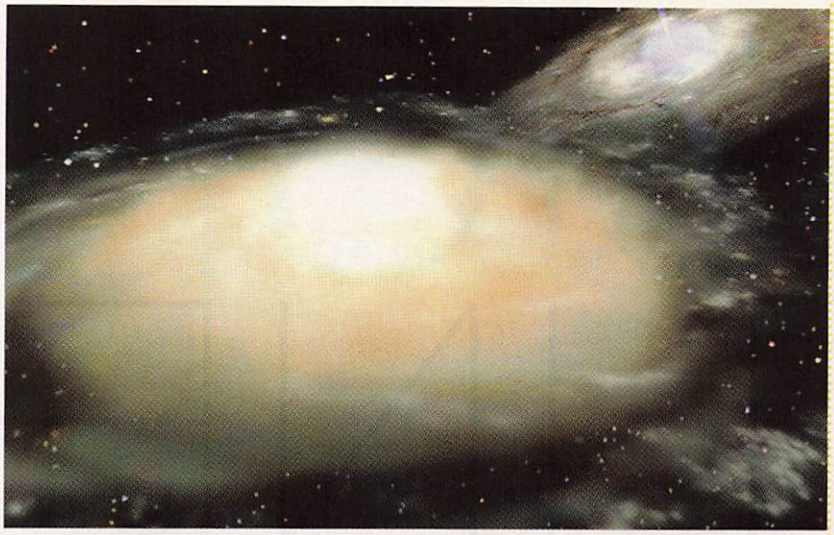
TOP: BILL FRYMIRE/MASTERFILE. BOTTOM: ERIKA LARSEN

ON TEGMARK'S NIGHTSTAND:

- *The Singularity Is Near: When Humans Transcend Biology* by Ray Kurzweil. “He's pushing this idea that within decades, computers will be smarter than us,” Tegmark says.
- Snore Stopper, a gadget that gives your wrist a mild electric shock when it detects snoring (“My wife, Angelica, and the kids love to make snoring sounds when I'm wearing it just to zap me on purpose.”)
- An iPod dock and a clock radio
- *The Time Trap* by Alec Mackenzie

The Black Hole War: My Battle With Stephen Hawking to Make the World Safe for Quantum Mechanics

by Leonard Susskind
(Little, Brown, $27.99)



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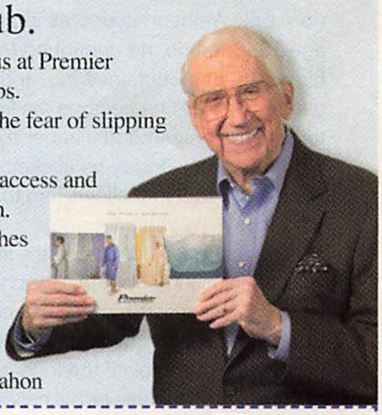
Say that the universe is a hologram. Say that reality is an illusion projected from lower dimensions. Say that you're even smarter than Stephen Hawking (at least when it comes to black holes and what dribbles out of them). If you're Leonard Susskind, father of string theory, then who knows? You might be right. Clear writing and a sprinkling of black-and-white doodles make this upward trudge through Theoretical Physics 101 (and 201) a satisfying haul. But if it's proof you want, come back next millennium. **Susan Kruglinski**

The Future of the Internet—and How to Stop It

by Jonathan Zittrain
(Yale University Press, $30)

Once a freewheeling frontier, the Internet is approaching lockdown as we trade freedom for the promise of security in our online lives, Oxford University cyberlaw scholar Jonathan Zittrain says. Viruses, spyware, malware, and spam are driving Internet users away from technologies like Wikipedia, which anyone can modify, toward appliances such as iPods, iPhones, Xboxes, and TiVos, which only their makers can modify. The control that the developers of these "tethered appliances" retain threatens to stifle the innovation that gave rise to the Internet, and it can be turned against us too—to spy on us, sell our secrets, silence dissent, and eliminate choice. Zittrain sounds the alarm in clear, compelling language and maps out a plan that could provide reasonable security without sacrificing what we most want to protect about the Internet. **Marion Long**



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SIGHT LINES

Can a blind climber "see" through pulses delivered to his tongue?

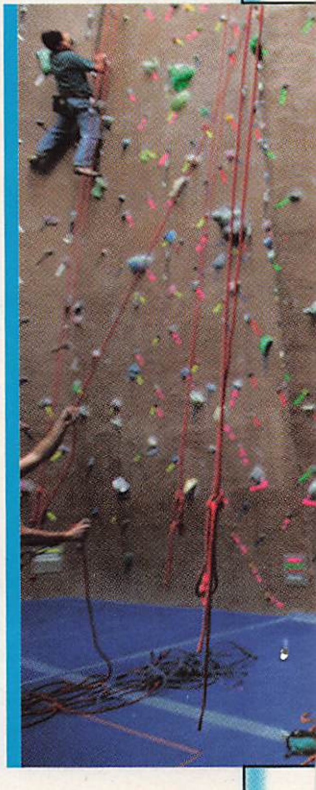
BY **BUDDY LEVY** PHOTOGRAPH BY **BETH WALD**

A **wiry man in his late 30s** hangs near the top of a 40-foot wall, the toes of his climbing shoes barely gripping the sheer face. He clings with his left hand and pauses, swinging his right arm to the side, loosening the muscles. Then he raises his head and lunges, thrusting his right hand above him and catching a rock hold with his fingertips. With a few more moves he arrives at the top. Under normal circumstances this extreme rock climber would be worth watching. But what makes his effort even more remarkable is that he happens to be blind. Born with retinoschisis, a rare disease akin to macular degeneration, Erik Weihenmayer was sightless by age 13. Even so, he continued to pursue his dream of mountaineering, and he succeeded: In 2001 he became the first—and to date the only—blind climber to summit Mount Everest. Today he is climbing with the aid of a tool that allows him to "see" in a new way—with his tongue.

In normal vision, light hitting the retina provokes electrical impulses that the brain translates into images. What the tool, called the BrainPort, does is convert light into electrical impulses that stimulate the tongue instead of the retina. With more tactile nerve endings than any other part of the body except the lips, the tongue can discriminate two points spaced less than a millimeter apart. That degree of resolution is far beyond what the current BrainPort array, with only 611 electrodes, provides. But tests have shown the BrainPort delivers enough information for users like Erik to navigate with.

"Climbing!" Erik calls out to his partner. He places the device in his mouth, raises his head, and "surveys" the wall before him. Electrical impulses from the BrainPort become to him "a tactile image that I'm interpreting in space." Erik reaches for a handheld slider that controls the zoom level and field of view of the BrainPort so that he can "see" one or two rock climbing holds on the wall some 2 or 3 feet above him. Then he slowly and deliberately raises his right hand, reaches up, grabs hold, and begins to pull himself up the wall. His feet secure, he hangs for a moment, adjusts the zoom again, then tentatively puts his hand out and above him again, this time missing the hold by half a foot. Judging the distance of an object in space is particularly difficult even with the device, Erik says. To help him figure out how far away something is, he sometimes waves his hand—an object of known size and distance—in front of himself first to get a sense of scale via the BrainPort array. The feedback helps him assess the distance of his next rock climbing hold.

Testing the BrainPort, Erik says, involves "learning to climb in a new, different way. I'm learning another language in the same way someone would be learning Braille or French for the first time. I'm figuring out



Erik Weihenmayer, a blind climber, reaches for a handhold using the BrainPort.

how to map it spatially." The challenges are significant. The BrainPort provides information in two dimensions, like a line drawing on a piece of paper, but the user's brain must learn to translate this information into things like perspective, dimension, and location in space. When Erik first used the BrainPort, the images in his brain appeared as unidentifiable shapes and lines, but over time, through practice, his brain adapted, eventually translating the tactile sensations into recognizable patterns and symbols.

Erik has experimented with the tool at his home in Golden, Colorado. He could find and grab a coffee cup placed on the center island in his kitchen; play soccer with his daughter Emma in their large downstairs playroom, kicking the ball back and forth over some 15 feet; play rock-paper-scissors; and compete in a game of tic-tac-toe by identifying *x*'s and *o*'s on paper mounted on an easel. Later, the two moved out to the snowy front yard to play hide-and-seek. Eventually Erik could detect Emma's movement as well as locate a snowman. Outdoor environments remain particularly challenging, though.

"Outside, shadows create lines, which appear on the tongue as objects in space," Erik says. "For sighted people, the eyes and the brain quickly make adjustments, but the BrainPort doesn't always keep pace with the shadows, and one has to learn to interpret these situations and contexts."

Paul Bach-y-Rita, the cocreator of the system Weihenmayer is testing, challenged conventional wisdom when he proposed that "we see with the brain, not with the eyes." He insisted that the brain was flexible enough to learn to interpret data coming in on a different kind of channel. Bach-y-Rita died in 2006, but Wicab—the company he cofounded in Middleton, Wisconsin, in 1998—continues to work on devices based on the idea that one sense can substitute for another. By 2004, Wicab had gained support for its research from the National Eye Institute, one of the federal agencies of the National Institutes of Health.

Wicab intends to create a BrainPort vision device for consumers, and over time the company has made it much less cumbersome. The prototype Erik first worked with in 2003 was bulky, comprising a webcam with a fixed field of view and a shoe box full of hardware that drove a basic 144-electrode array, all connected and run through a laptop computer. The current BrainPort prototype includes hardware contained in a belt-mounted 6-by-6-by-4-inch box, three sensitive cameras with a 90-degree field of view, and user-operated zoom and contrast control.

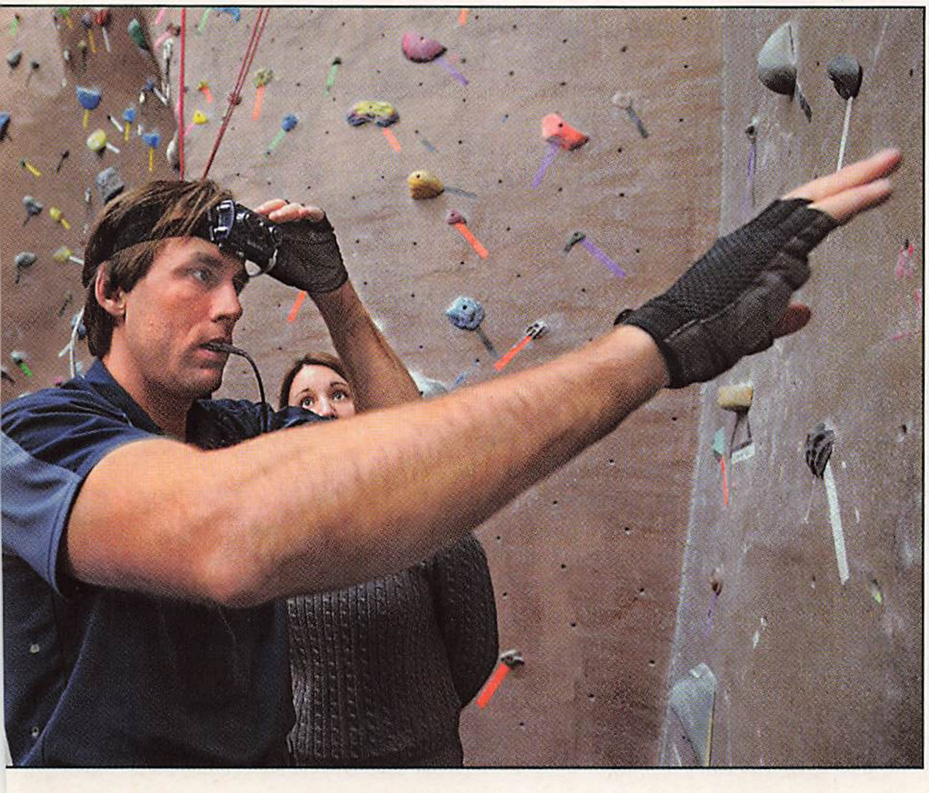
Still, despite significant improvements in size and portability, the current prototype is not cosmetically appealing or portable enough for ordinary use. Wicab plans eventually to integrate microcameras and microprocessors into eyeglass frames; a dental appliance will incorporate the tongue display, allowing the user to touch the display intentionally with the tongue, but also to pull it away and talk. Low-power radio frequency transceivers will link the cameras, processors, and tongue arrays; later on, wireless technology will connect these elements.

Other applications for the BrainPort include assisting military divers in challenging low-light and no-light search-and-rescue operations, says Rich Hogle, Wicab director of product development. "Imagine that you're floating in a dense brown fog in daytime and visibility is such that ... there's no up, down, left, or right, and now your job is to swim 200 yards in a straight, level line, turn 180 degrees to the left, and swim back in a line parallel to the first. If you're off by a few degrees in either direction, or too shallow or too deep, you might miss what you are looking for. Now imagine doing the same thing, in the same brown fog, at night."

In research funded by the Defense Advanced Research Projects Agency, Wicab researchers used BrainPort technology to help military divers swim in a straight line in low-light and no-light conditions. "For this project we used a digital compass to provide directional information that was then displayed on the tongue as a tactile pattern," Hogle says. "While swimming in the target direction, the diver's eyes and ears were able to remain focused on the operational tasks at hand."

Erik Weihenmayer hopes that the device will eventually benefit other members of the blind community, especially those who have never experienced vision. "I wonder how great one's learning curve would be if you used this device two hours a day, every day. All of these blobs and circles and lines you would be able to learn and interpret. If you gave it to a blind child, his spatial understanding of the world would be through his tongue. It's a compelling thought."

The BrainPort provides a window into the vast complexity of our senses, Weihenmayer says. "I'm reminded how amazing the brain really is, with its incredible ability to differentiate all this information. It's a trip to be able to 'look' at a hold and reach for it. For me, it's beyond science. It's a kind of vision." ■



MIND GAMES

By Scott Kim

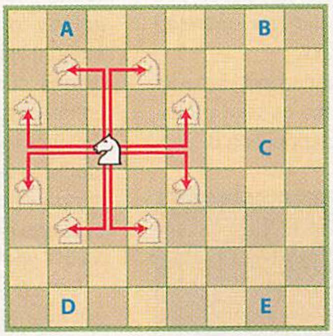
SMART MOVES

This fall, Idaho will become the first state to offer chess as an optional part of its statewide curriculum. The program, called First Move, is for second- and third-grade students and was developed by America's Foundation for Chess (af4c.org), a Seattle-based organization that promotes teaching chess in schools. Idaho's Department of Education hopes that within a few years all elementary schools in the state will offer chess as a learning tool.

Like all good games, chess encourages students to think on their feet as they cope with complex, unpredictable, and shifting situations.

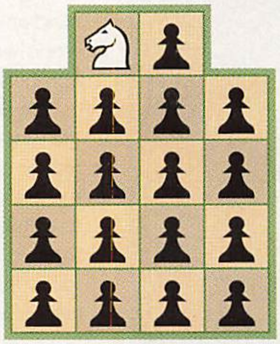
First Move doesn't require that teachers already play chess well—or even at all. The program provides training, support, and classroom materials that help students learn the rules of the game. The following puzzles are based on exercises from First Move.

KNIGHT'S CRUSADE

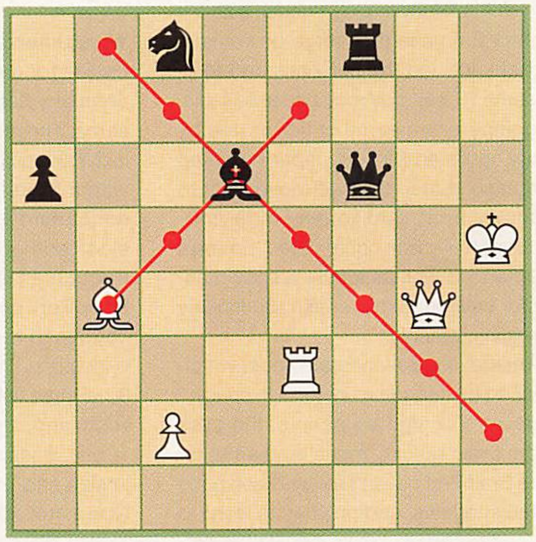


Different chess pieces move in different ways. The knight, which looks like a horse's head, moves in an L-shaped path that travels two squares horizontally or vertically, then one square to either side. The knight at right, for instance, can jump to any one of eight squares, as shown by the red arrows.

1. How many moves are required for the knight to reach each of the squares labeled A through E, above? For example, it takes at least two moves for the knight to reach square A.
2. The knight captures a piece of the opposite color by moving into the square it occupies. The captured piece is then removed and the knight remains. The knight is allowed to jump over other pieces to get to its destination square, but it captures only the piece it lands on, not any of the pieces it might jump over. The white knight on the board at bottom left has been surrounded by black pawns. Your challenge is to capture all 17 pawns by making a series of moves with the white knight. You must capture a pawn on every move.

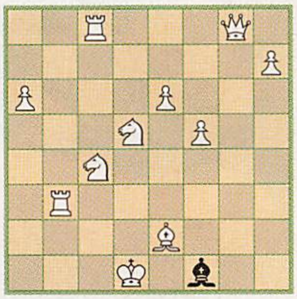


BISHOP'S PATH



The bishop, which looks like a bishop's pointy miter, moves by sliding along a diagonal line to another square. The bishop can capture a piece of the opposite color by landing on its square, but unlike the knight, it cannot jump over other pieces. The black bishop on the board above, for example, can move to any one of the squares marked with a red dot.

1. Moving only the black bishop, capture all the white pieces on the board at right, ending in the bottom row with the King, which looks like a crown. You must capture a piece on every move.
2. Which piece can you remove while still being able to capture all the white pieces in a series of moves, one capture each move, ending at the King? There is more than one solution.



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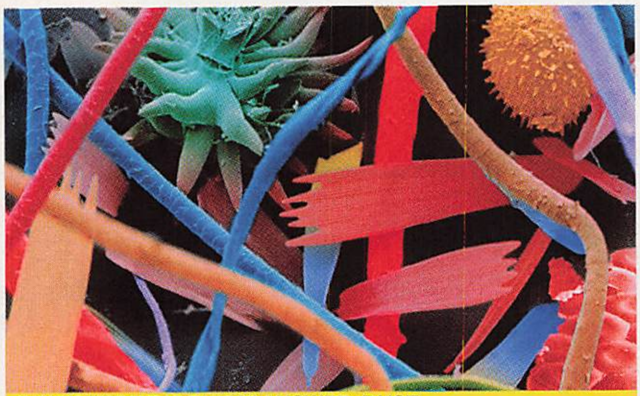
MIND GAMES SOLUTIONS

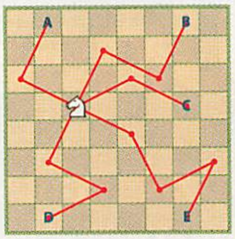


JUNE'S "WHAT IS THIS?" ANSWER: DUST

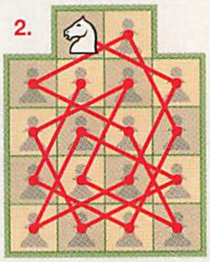
This false-color image of household dust was captured with a scanning electron microscope at 115x, giving a cozy view of the allergens within—including cat hair, synthetic fibers, pollen, and even insect scales. The Centers for Disease Control says household dust is a "major source of lead" and encourages people to mop floors and wipe surfaces with a wet rag, for health's sake. The National Institutes of Health has also found that bacteria in dust can trigger asthma. To study the health hazards, the government sells 10-gram samples of dust to researchers for $475.

KNIGHT'S CRUSADE

1. The shortest paths are shown at right. (There are several equally short variations for most of these moves.)
A=2 moves, B=3 moves, C=2 moves, D=3 moves, E=4 moves

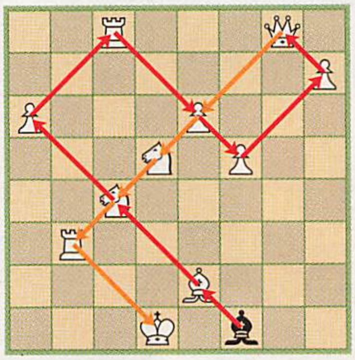


2.

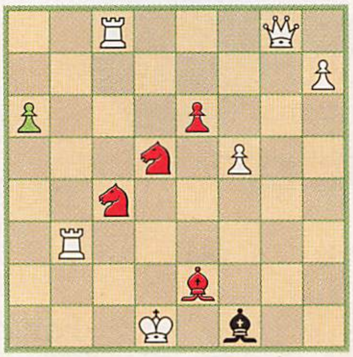


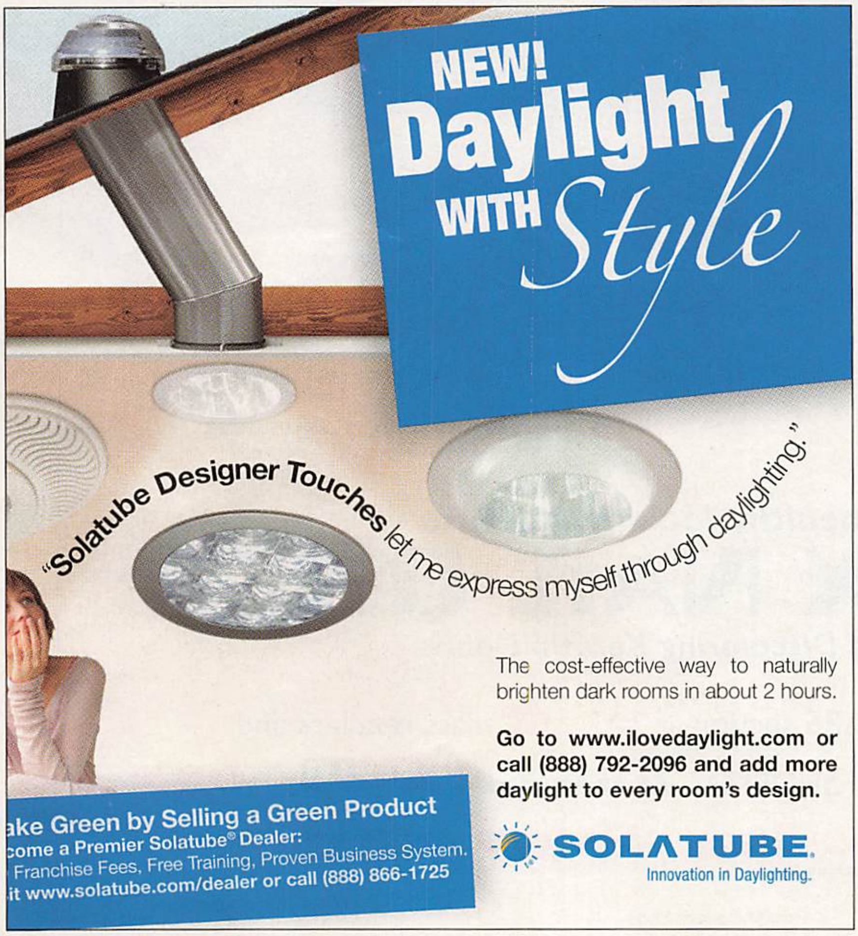
BISHOP'S PATH

1. Here is the unique solution path.



2. Any one of the red pieces can be removed without disturbing the solution path. Alternatively, the green pawn can be removed, resulting in a different solution path that doubles back on itself after the rook in the top row is captured.





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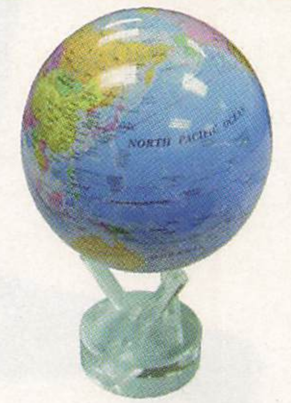

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20 THINGS YOU DIDN'T KNOW ABOUT OIL

1 This list is about black gold. Texas tea. Petroleum, or crude oil. Which is in no way related to the oils we eat or excrete.

2 If you are a creationist, crude oil was formed by thousands of years of heat and pressure applied to the carcasses of plants and animals that died in the Great Flood. If you're not, you think oil comes from dinosaurs, right?

3 Wrong. Almost all oil comes from pressure-cooking dead zooplankton and algae—pond scum, in other words—which are among the oldest and most abundant life forms on earth.

4 Don't blame the Hummers. That pond scum ultimately produced trillions upon trillions of gallons of oil. But most of it bubbled up to the surface long ago and was consumed by greedy bacteria.

5 Oil companies seek the small fraction that remains, spending more than $150 billion a year hunting for new reserves.

6 Fashion march of the penguins: Thousands of tiny, colorful sweaters have been knit for these flightless birds, to keep them from preening themselves if they are doused in oil from a spill.

7 When you buy gasoline, you might want to make your purchase at night—it will be cheaper. Gasoline becomes more dense in cooler temperatures, and gas pumps measure gas by volume.

8 A tip for trippers: Keep your windows closed at high speeds—drag from open windows can reduce a car's fuel efficiency by 10 percent.

9 Neatness counts too: Cleaning 100 pounds of junk from your car will get you up to 2 percent more miles per gallon.

10 Another trip tip: Instead of taking a break for lunch at a restaurant, cook food on your engine. Find out how (and get a recipe for Hyundai Halibut With Fennel) in the classic book *Manifold Destiny.*

11 The recipe for gasoline itself is complex. Depending on the blend, it can contain between 150 and 1,000 different chemical compounds.

12 Tighten your gas cap. A leaking or missing cap can release 30 gallons of fuel per year into the atmosphere.

13 In California alone, vapors from gas stations account for enough gasoline to fill two tanker trucks every day.

TOM SCHIERLITZ/GETTY IMAGES

14 Speaking of tankers, that truck you're trying to pass may be carrying 4,000 gallons of gas, which, if in a crash, can explode with the energy of 200 tons of TNT.

15 By the eighth century, a petroleum industry already existed in the Middle East. The streets of Baghdad were paved with tar derived from petroleum.

16 In oil-rich Baku, Azerbaijan, north of Iran, villagers could once dig a hole in the ground with their hands, drop in a live coal, and start a fire.

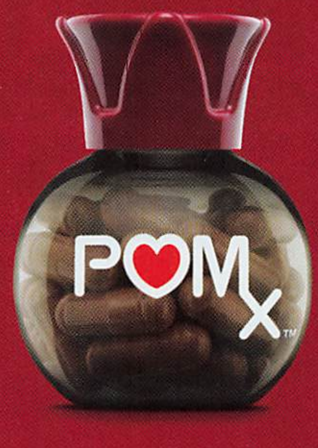
17 In the United States, when people first noticed oil, they didn't quite grasp the energy angle. Instead they did what any industrious American would do: They bottled it, slapped a label on, and sold it as a health tonic.

18 Several hundred thousand bottles of the stuff are said to have been purchased and, perhaps, consumed.

19 Since they moved on from the health drink angle, Americans have laid down 161,000 miles of fuel pipeline in the United States. That's more than half the distance to the moon.

20 Spies like pipelines. Engineers use a robotic device known as a smart pig to inspect pipelines from the inside. Two James Bond movies so far have made oil pipelines and pigs part of the plot: *The Living Daylights* and *The World Is Not Enough.* You will have to wait until November to see if the pattern is repeated in the next Bond installment, *Quantum of Solace.*

Susan Kruglinski



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